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Specification

Light control film and backlight unit using the same

[Technical Field]

[0001]

The present invention relates to a light control film used for backlight units such as those for liquid crystal displays and so forth, and a backlight unit using the same.

[Background Art]

[0002]

For liquid crystal displays and so forth, backlight units of the edge light type or direct type are conventionally used. Since backlight units of the edge light type themselves can be manufactured with a small thickness, they are used for notebook computers etc., whereas backlight units of the direct type are used for large-sized liquid crystal television etc. in many cases.

[0003]

Lights emitted from these conventional backlight units contain components projected along directions significantly inclined from the direction the front direction. Lights emitted from backlight units of the edge light type, in particular, contain a lot of components projected along directions significantly inclined from the front direction, and thus it is difficult to obtain high front luminance.

[0004]

In the conventional backlight units, two or more optical films such as prism sheets and light diffusive films are used in combination in order to improve front luminance so that directions of lights should be directed to the front direction (see, for example, Patent document

1).

[0005]

Although prism sheets can generally increase the ratio of lights emerging along the front direction (direction perpendicular to film surface) by surface design based on geometric optics. However, they have drawbacks that they are likely to suffer from an interference pattern due to regularly arranged convex portions, and that they cause glare if they are used alone and thus they impair visibility of image. Moreover, they unduly concentrate lights along the front direction, and therefore they cannot provide a wide viewing angle.

[0006]

On the other hand, if diffusion films are used alone, the front luminance becomes insufficient, although the aforementioned problems are not caused.

[0007]

In the technique disclosed in Patent document 1, a prism sheet and a light diffusive film are used in combination. However, the front luminance enhanced by the prism sheet is reduced by the use of the light diffusive film. Moreover, the films placed in layers may generate Newton rings between the members, or scratches and so forth may be generated due to the contact of the members as the case may be.

[0008]

[Patent document 1] Japanese Patent Unexamined Publication (KOKAI) No. 9-127314 (claim 1, paragraph 0034)

[Disclosure of the Invention]

[Problems to be solved by the Invention]

[0009]

Therefore, an object of the present invention is to provide a light control film that can surely improve front

luminance when it is used alone or in combination with a prism sheet, has an appropriate light diffusing property, and does not suffer from the problems of interference pattern and glare, and a backlight unit using the same.

[Means for Achieving the Object]

[0010]

In order to achieve the aforementioned object, the inventor of the present invention conducted various researches on various factors defining surface profile of light control film such as shapes, slopes with respect to film surface(base plane), heights and pitches of convexoconcaves (protrusion and recess) and so forth, and as a result, he found that the front luminance could be improved by appropriately controlling the slopes of the curved surface constituting the rough surface with respect to the base plane and thereby efficiently directing lights entered into the film to the front direction (projection direction).

[0011]

More specifically, they found that superior front luminance could be achieved if average (θ_{nv} (degree)) of slopes of the curved surface of the rough surface with respect to the standard surface (the surface opposite to the surface on which convexoconcaves are formed), which slopes are henceforth referred to as "slopes of a curved surface", obtained for an area of a particular size or larger (1 mm^2 or larger) was within a predetermined range, as defined in the first to fourth embodiments of the present invention.

It was further found that if the average of slopes of the curved surface (θ_{nv} (degree)) was used as an index of slope of the rough surface, and a ratio of an area (A_1) of an approximately square region on the rough surface (area

of orthogonal projection of the rough surface) and a surface area (A_2) of a curved surface constituting the rough surface ($A_r = A_2/A_1$) was used as an index of height of convexoconcaves, relations of these indexes with change of front luminance could be described by particular relational equations, and when the values of the indexes were within specific ranges, superior front luminance could be achieved, and thus accomplished the first to fourth embodiments of the present invention.

[0013]

That is, the light control film according to the first embodiment of the present invention is a light control film having a rough surface, wherein, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm^2 or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, an average of slopes of the curved surface (θ_{nv} (degree)) of the rough surface with respect to a base plane of the film is not less than 27 degrees and not more than 70 degrees at substantially any position on the light control film (a condition providing θ_{nv} not less than 27 degrees and not more than 70 degrees is called "condition 1" hereafter).

[0014]

The light control film according to the second embodiment of the present invention is a light control film having a rough surface formed by a patterned layer comprising a material having a refractive index n , wherein, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm^2 or

larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, an average of slopes of the curved surface (θ_{nv} (degree)) of the rough surface with respect to a base plane of the film is not less than $(59 - 20n)$ degrees and not more than 70 degrees at any position on the light control film (a condition providing θ_{nv} not less than $(59 - 20n)$ degrees and not more than 70 degrees is called "condition 2" hereafter).

[0015]

Further, the light control film according to the third embodiment of the present invention is a light control film having a rough surface, wherein, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm^2 or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, an average of slopes of the curved surface (θ_{nv} (degree)) of the rough surface with respect to a base plane of the film and a ratio of an area of the approximately square region (A_1) and a surface area of the approximated curved surface of the rough surface (A_2) ($A_r = A_2/A_1$) satisfy the following equation (1) or (2) at substantially any position on the light control film (a condition providing θ_{nv} and A_r that satisfy " $\theta_{nv} \div A_r \geq 22$ " or " $30 \leq \theta_{nv} \times A_r \leq 140$ " is called "condition 3" hereafter).

$$\theta_{nv} \div A_r \geq 22 \quad (1)$$

$$30 \leq \theta_{nv} \times A_r \leq 140 \quad (2)$$

[0016]

The light control film according to the fourth embodiment of the present invention is a light control film having a rough surface formed by a patterned layer comprising a material having a refractive index n , wherein, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm^2 or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, an average of slopes of the curved surface (θ_{nv} (degree)) of the rough surface with respect to a base plane of the film and a ratio of an area of the approximately square region (A_1) and a surface area of the approximated curved surface of the rough surface (A_2) ($A_r = A_2/A_1$) satisfy the following equation (3) or (4) at substantially any position on the light control film (a condition providing θ_{nv} and A_r that satisfy " $\theta_{nv} \div A_r \times n^2 \geq 35$ " or " $60 \leq \theta_{nv} \times A_r \times n^2 \leq 350$ " is called "condition 4" hereafter).

$$\theta_{nv} \div A_r \times n^2 \geq 35 \quad (3)$$

$$60 \leq \theta_{nv} \times A_r \times n^2 \leq 350 \quad (4)$$

[0017]

Aiming at achieving the aforementioned object, it was also found that if average (θ_{nv} (degree)) of slopes of a curved surface of the rough surface with respect to the standard surface (the surface opposite to the surface on which convexoconcaves are formed), which slopes are henceforth referred to as "slopes of a curved surface", obtained for an area of a particular size or larger (1 mm^2 or larger) was within a predetermined range, and a numerical value A_{sk} [equation (5)] representing an index of asymmetry of a probability density function for the height direction obtained from all the surface height data for the

aforementioned area, or a numerical value A_{ku} [equation (6)] representing as an index of sharpness of the probability density function for the height direction obtained from all the surface height data was within a predetermined range, as defined in the fifth to eighth embodiments of the present invention, superior front luminance could be achieved.

[0018]

[# 1]

$$A_{sk} = \frac{\sum_{i=1}^m z_i^3}{m} \bigg/ \sqrt{\frac{\sum_{i=1}^m z_i^2}{m}} \quad \dots (5)$$

[In the equation (5), z_i represents a value obtained by subtracting a height of average plane of the rough surface from a measured surface height, and m represents a number of measurement points.]

[0019]

[# 2]

$$A_{ku} = \frac{\sum_{i=1}^m z_i^4}{m} \bigg/ \sqrt{\frac{\sum_{i=1}^m z_i^2}{m}} \quad \dots (6)$$

[In the equation (6), z_i represents a value obtained by subtracting a height of average plane of the rough surface from a measured surface height, and m represents a number of measurement points.]

[0020]

That is, the light control film according to the fifth embodiment of the present invention is a light control film having a rough surface, wherein a condition

that, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm^2 or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, an average of slopes of the curved surface (θ_{nv} (degree)) of the rough surface with respect to a base plane of the film is not less than 27 degrees and not more than 70 degrees, and an absolute value of a numerical value (A_{sk}) calculated in accordance with the equation (5) by using all the height data of the rough surface is not more than 1.2 is satisfied at substantially any position on the light control film (the condition providing θ_{nv} not less than 27 degrees and not more than 70 degrees and an absolute value of A_{sk} not more than 1.2 is called "condition 5" hereafter).

[0021]

The light control film according to the sixth embodiment of the present invention is a light control film having a rough surface formed by a patterned layer comprising a material having a refractive index n , wherein a condition that, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm^2 or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, an average of slopes of the curved surface (θ_{nv} (degree)) of the rough surface with respect to a base plane of the film is not less than $(59 - 20n)$ degrees and not more than 70 degrees, and an absolute value of a numerical value (A_{sk}) calculated in accordance with the equation (5)

by using all the height data of the rough surface is not more than 1.2 is satisfied at substantially any position on the light control film (the condition providing θ_{nv} not less than $(59 - 20n)$ degrees and not more than 70 degrees and an absolute value of A_{sk} not more than 1.2 is called "condition 6" hereafter).

[0022]

Further, the light control film according to the seventh embodiment of the present invention is a light control film having a rough surface, wherein a condition that, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm^2 or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, an average of slopes of the curved surface (θ_{nv} (degree)) of the rough surface with respect to a base plane of the film is not less than 27 degrees and not more than 70 degrees, and a numerical value (A_{ku}) calculated by using all the height data of the rough surface in accordance with the aforementioned equation (6) is not less than 1.5 and not more than 5.0 is satisfied at substantially any position on the light control film (the condition providing θ_{nv} not less than 27 degrees and not more than 70 degrees and A_{ku} not less than 1.5 and not more than 5.0 is called "condition 7" hereafter).

[0023]

Furthermore, the light control film according to the eighth embodiment of the present invention is a light control film having a rough surface formed by a patterned layer comprising a material having a refractive index n , wherein a condition that, for a curved surface of the rough

surface approximated in an approximately square region having an area of 1 mm^2 or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, an average of slopes of the curved surface (θ_{nv} (degree)) of the rough surface with respect to a base plane of the film is not less than $(59 - 20n)$ degrees and not more than 70 degrees, and a numerical value (A_{ku}) calculated by using all the height data of the rough surface in accordance with the aforementioned equation (6) is not less than 1.5 and not more than 5.0 is satisfied at substantially any position on the light control film (the condition providing θ_{nv} not less than $(59 - 20n)$ degrees and not more than 70 degrees and a value of A_{ku} not less than 1.5 and not more than 5.0 is called "condition 8" hereafter).

[0024]

Aiming at achieving the aforementioned object, it was also found that if a ratio ($A_r = A_2/A_1$, referred to as a surface area ratio hereafter) of a surface area (A_2) of a curved surface constituting the rough surface and an area (A_1) of an approximately square region on the rough surface (area of orthogonal projection of the rough surface) was within a predetermined range, and a numerical value A_{sk} [equation (5)] representing an index of asymmetry of a probability density function for the height direction obtained from all the surface height data for the area (A_1), or a numerical value A_{ku} [equation (6)] representing an index of sharpness of the probability density function for the height direction obtained from all the surface height data was within a predetermined range, as defined in the ninth to twelfth embodiments of the present invention,

superior front luminance could be achieved.

[0025]

[# 3]

$$A_{sk} = \frac{\sum_{i=1}^m z_i^3}{m} \bigg/ \sqrt[3]{\frac{\sum_{i=1}^m z_i^2}{m}} \quad \dots (5)$$

[In the equation (5), z_i represents a value obtained by subtracting a height of average plane of the rough surface from a measured surface height, and m represents a number of measurement points.]

[0026]

[# 4]

$$A_{ku} = \frac{\sum_{i=1}^m z_i^4}{m} \bigg/ \sqrt[4]{\frac{\sum_{i=1}^m z_i^2}{m}} \quad \dots (6)$$

[In the equation (6), z_i represents a value obtained by subtracting a height of average plane of the rough surface from a measured surface height, and m represents a number of measurement points.]

[0027]

Thus, the light control film according to the ninth embodiment of the present invention is a light control film having a rough surface, wherein a condition that, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm² or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, a

ratio of an area of the approximately square region (A_1) and a surface area of the approximated curved surface of the rough surface (A_2) ($A_r = A_2/A_1$) is not less than 1.2 and not more than 2.5, and absolute value of a numerical value (A_{sk}) calculated in accordance with the equation (5) by using all the height data of the rough surface is not more than 1.2 is satisfied at substantially any position on the light control film (the condition providing A_r not less than 1.2 and not more than 2.5 and an absolute value of A_{sk} not more than 1.2 is called "condition 9" hereafter).

[0028]

The light control film according to the tenth embodiment of the present invention is a light control film having a rough surface formed by a patterned layer comprising a material having a refractive index n , wherein a condition that, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm^2 or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, a ratio of an area of the approximately square region (A_1) and a surface area of the approximated curved surface of the rough surface (A_2) ($A_r = A_2/A_1$) is not less than $(2 - 0.5n)$ and not more than 2.5, and absolute value of a numerical value (A_{sk}) calculated in accordance with the equation (5) by using all the height data of the rough surface is not more than 1.2 is satisfied at substantially any position on the light control film (the condition providing A_r not less than $(2 - 0.5n)$ and not more than 2.5 and an absolute value of A_{sk} not more than 1.2 is called "condition 10" hereafter).

[0029]

Further, the light control film according to the eleventh embodiment of the present invention is a light control film having a rough surface, wherein a condition that, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm^2 or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, a ratio of an area of the approximately square region (A_1) and a surface area of the approximated curved surface of the rough surface (A_2) ($A_r = A_2/A_1$) is not less than 1.2 and not more than 2.5, and a numerical value A_{ku} calculated in accordance with the equation (6) mentioned above by using all the surface height data is not less than 1.5 and not more than 5.0 is satisfied at substantially any position on the light control film (the condition providing A_r not less than 1.2 and not more than 2.5 and A_{ku} not less than 1.5 and not more than 5.0 is called "condition 11" hereafter).

[0030]

The light control film according to the twelfth embodiment of the present invention is a light control film having a rough surface formed by a patterned layer comprising a material having a refractive index n , wherein, for a curved surface of the rough surface approximated in an approximately square region having an area of 1 mm^2 or larger defined at an arbitrary position on the rough surface by using height data of the rough surface measured with predetermined intervals for the longitudinal and transverse directions in the approximately square region, a ratio of an area of the approximately square region (A_1) and a surface area of the approximated curved surface of

the rough surface (A_2) ($A_r = A_2/A_1$) is not less than $(2 - 0.5n)$ and not more than 2.5, and a numerical value A_{ku} calculated in accordance with the equation (6) mentioned above by using all the surface height data is not less than 1.5 and not more than 5.0 at substantially any position on the light control film (the condition providing A_r not less than $(2 - 0.5n)$ and not more than 2.5 and A_{ku} not less than 1.5 and not more than 5.0 is called "condition 12" hereafter).

[0031]

In the first to twelfth embodiments of the present invention, the area of the approximately square region on the rough surface means an area of the orthogonal projection of the rough surface.

[0032]

In the first to twelfth embodiments of the present invention, the base plane of the film means a plane of the film regarded substantially planar, and when the face of the light control film of the present invention opposite to the face on which convexoconcaves are formed is smooth, the plane of this face can be regarded as the base plane. When the opposite face is not smooth but a rough surface, a plane including the central lines of two different directions thereof can be regarded as the base plane.

[0033]

In the first to eighth embodiments of the present invention, the average of slopes of a curved surface (θ_{nv} (degree)) is used. In general, if a curved surface of a rough surface can be represented with a common function $z = f(x, y)$, an average of slopes of the curved surface (C_{fc}) constituting the rough surface with respect to the aforementioned base plane can be represented by the following equation (7) wherein D is a region for which the

average is calculated.

[0034]

[# 5]

$$C_{fc} = \iint_D \left(\frac{\partial z}{\partial x} + \frac{\partial z}{\partial y} \right) dx dy / \iint_D dx dy \quad \dots (7)$$

[0035]

Further, the average of slopes of the curved surface wherein the slopes are indicated with angle (θ_{fc} (degree)) can be represented by the following equation (8).

[0036]

[# 6]

$$\theta_{fc} = \tan^{-1} C_{fc} \quad \dots (8)$$

[0037]

However, although it is possible to use such a function for product designing, it is almost impossible to describe a rough surface with a general function for an actual product, and average of slopes of a curved surface (θ_{fc} (degree)) can hardly be obtained, either. Therefore, in the first to eighth embodiments of the present invention, a value calculated as follows is defined as an average of slopes of a curved surface (θ_{nv} (degree)).

[0038]

First, surface height data of a rough surface are measured by using a surface profiler at positions defined by dividing an approximately square region of an area larger than a particular area (1 mm^2 or larger) at an arbitrary position on the rough surface in a lattice pattern with predetermined intervals (Δd_L , Δd_H) for the longitudinal and transverse directions. When the surface height data for the approximately square region on the base plane are measured at points in numbers of r for the

longitudinal direction and s for the transverse direction, the height data correspond to those of points in a number of $(r \times s)$, and the respective data points are represented as $\{(H_{11}, H_{12}, H_{13}, \dots H_{1s}), (H_{21}, H_{22}, H_{23}, \dots H_{2s}), \dots (H_{r1}, H_{r2}, H_{r3}, \dots H_{rs})\}$. The numbers of the measurement points for the longitudinal and transverse directions, r and s , may be the same or different, so long as the region is approximately square. Further, the measurement intervals for the longitudinal and transverse directions, Δd_L and Δd_H , may also be the same or different.

[0039]

Then, one diagonal line is drawn in each unit lattice having side lengths of Δd_L and Δd_H for the longitudinal and transverse directions on the base plane to divide the lattice into two triangles. From height data at the positions of three apexes of each of these two triangles on the base plane, "one triangle plane (henceforth referred to as "minute triangle plane")" is uniquely defined for each triangle on the base plane, and slope of this minute triangle plane with respect to the base plane can be obtained by obtaining the angle between the normal of the minute triangle plane and the normal of the base plane through calculation. If Δd_L and Δd_H are sufficiently small, it can be regarded that the curved surface constituting the rough surface is approximated with planes of the minute triangles. Therefore, the average of slopes of the curved surface (θ_{nv} (degree)) can be obtained by applying this method to all the unit lattices in the approximate square for which the height data are measured to approximate the curved surface constituting the rough surface with planes of minute triangles, obtaining slopes of the minute triangle planes and averaging the slopes.

[0040]

The lengths of the measurement intervals (Δd_L and Δd_H) mentioned above are such lengths that the profile of the rough surface included in the measurement region can be sufficiently correctly reflected, and both are specifically intervals of about 1.0 μm or shorter.

[0041]

On the other hand, in the third, fourth and ninth to twelfth embodiments of the present invention, the surface area of a curved surface constituting the rough surface (A2) is used. In general, if a curved surface of a rough surface can be represented with a common function $z = f(x, y)$, the surface area of the curved surface constituting the rough surface (A2) can be represented by the following equation (9) wherein D is a region for which the average is calculated.

[0042]

[# 7]

$$A2 = \iint_D \sqrt{1 + \left(\frac{\partial z}{\partial x}\right)^2 + \left(\frac{\partial z}{\partial y}\right)^2} dx dy \quad \dots (9)$$

[0043]

However, although it is possible to use such a function for product designing, it is almost impossible to describe a rough surface with a general function for an actual product, and therefore the surface area (A2) can hardly be obtained, either. Therefore, in the third, fourth and ninth to twelfth embodiments of the present invention, a value calculated as follows is defined as the surface area of a curved surface (A2).

[0044]

First, surface height data of the rough surface are measured by using a surface profiler at positions defined by dividing an approximately square region of an area

larger than a particular area (1 mm^2 or larger) at an arbitrary position on the rough surface in a lattice pattern with predetermined intervals (Δd_L , Δd_H) for the longitudinal and transverse directions. When the surface height data for the approximately square region on the base plane are measured at points in numbers of r for the longitudinal direction and s for the transverse direction, the total data correspond to those of points in a number of $(r \times s)$, and the respective data points are represented as $\{(H_{11}, H_{12}, H_{13}, \dots H_{1s}), (H_{21}, H_{22}, H_{23}, \dots H_{2s}), \dots (H_{r1}, H_{r2}, H_{r3}, \dots H_{rs})\}$. The numbers of the measurement points for the longitudinal and transverse directions, r and s , may be the same or different, so long as the region is approximately square. Further, the measurement intervals for the longitudinal and transverse directions, Δd_L and Δd_H , may also be the same or different.

[0045]

Then, one diagonal line is drawn in each unit lattice having lengths of Δd_L and Δd_H for the longitudinal and transverse directions on the base plane to divide the lattice into two triangles. From height data at the positions of three apexes of each of these two triangles on the base plane, "one triangle plane (henceforth referred to as "minute triangle plane")" is uniquely defined for each triangle on the base plane, and area of this minute triangle plane can be obtained by calculation. If Δd_L and Δd_H are sufficiently small, it can be regarded that the curved surface constituting the rough surface is approximated with planes of minute triangles. Therefore, the curved surface area (A_2) can be obtained by applying this method to all the unit lattices in the approximate square for which the height data are measured to approximate the curved surface constituting the rough

surface with planes of minute triangles, obtaining areas of the minute triangle planes and summing the areas.

[0046]

The lengths of the measurement intervals (Δd_L and Δd_H) mentioned above are such lengths that the profile of the rough surface included in the measurement region can be sufficiently correctly reflected, and both are specifically intervals of about 1.0 μm or shorter.

[0047]

Further, the light control film according to the thirteenth embodiment of the present invention is the light control film according to any one of the first to twelfth embodiments mentioned above, wherein absolute value of average (ϕ_{ave}) of angles (ϕ , $-180 \text{ degrees} < \phi \leq 180 \text{ degrees}$) between orthogonal projections of normals of the curved surface of the rough surface projected on the base plane and one side of the approximately square region is not more than 5 degrees irrespective of the direction along which the approximately square region is defined in the rough surface (the condition providing an absolute value of the average (ϕ_{ave}) not more than 5 is referred to as "conditions 13" hereafter). If the condition 13 for ϕ_{ave} is satisfied for the approximately square region defined along an arbitrary direction within the rough surface, glare of the light control film can further be prevented. In order to obtain such a light control film satisfying the condition 13, multiple convex portions constituting the rough surface preferably substantially independent from one another, and each convex portion preferably consists of such a revolution body as shown in Fig. 2-2 as described later.

[0048]

A backlight unit according to the fourteenth

embodiment of the present invention is a backlight unit comprising a light guide plate equipped with a light source end portion thereof and having a light emergent surface approximately perpendicular to the end portion and a light control film provided on the light emergent surface of the light guide plate, wherein the aforementioned light control film is used as the light control film. A backlight unit according to the fifteenth embodiment of the present invention is the aforementioned backlight unit, wherein a prism sheet is used between the light control film and the light guide plate.

[0049]

A backlight unit according to the sixteenth embodiment of the present invention is a backlight unit comprising a light source, a light diffusive plate provided on one side of the light source and a light control film provided on the side of the light diffusive plate opposite to the light source side, wherein the aforementioned light control film is used as the light control film.

[Effect of the Invention]

[0050]

The light control film according to any one of the first to thirteenth embodiments of the present invention can increase components of lights of the front direction, in particular, those in the range of emergent angle of 0 to 30 degrees, for lights entered from the surface opposite to the rough surface and emerging from the rough surface, and thus it can attain markedly higher front luminance compared with usual diffusing films. In addition, it also has appropriate light diffusing property and does not generate glare and interference pattern.

[0051]

Further, the backlight unit according to the

fourteenth or fifteenth embodiment of the present invention is a backlight unit providing high front luminance, having appropriate light diffusing property, and not generating glare and interference pattern, because it uses the particular light control film. Moreover, it can prevent generation of scratches on a prism sheet due to contact with other members and so forth.

[Best Mode of Carrying Out the Invention]

[0052]

Hereafter, the light control film and backlight unit of the present invention will be explained in detail with reference to the drawings. The sizes (thickness, width, height etc.) of the elements illustrated in the drawings used for explanation of the present invention are enlarged or reduced as required for explanation and do not reflect actual sizes of the elements of actual light control film and backlight unit.

[0053]

Figs. 1 (a) to (c) schematically show examples of the light control film of the present invention. As shown in the drawings, the light control film of the present invention has fine convexoconcaves formed on one face of a substantially planar film and has a characteristic profile of the convexoconcaves. The convexoconcaves may be formed on a layer provided on one face of a film used as a substrate as shown in (a) and (b), or the light control film may be constituted with a single layer on which convexoconcaves are formed as shown in (c).

[0054]

When lights enter into the light control film of the present invention from the surface opposite to the surface on which convexoconcaves are formed and emerge from the rough surface, the light control film of the present

invention controls direction of the lights so that components of lights emerging with an angle with respect to the front direction within a predetermined range should increase to enhance front luminance, and light diffusing property which can prevent glares should be provided. Although the surface opposite to the surface on which convexoconcaves are formed is typically a smooth surface, it is not limited to a smooth surface. For example, matting may be performed or a predetermined dot pattern etc. may be formed on the surface.

[0055]

Hereafter, the conditions concerning the profile of the convexoconcaves for controlling direction of lights described above will be explained.

[0056]

In the present invention, conditions for obtaining optimum emergent lights were first investigated for a single convex portion (Fig. 2-2) consisting of a revolution body formed by rotating such an arbitrary curve as shown in Fig. 2-1 on a xy-plane as a base plane around a z-axis perpendicular to the xy-plane by simulating relationship between incident lights and emergent lights in a three-dimensional space with changing the convex shape, height thereof, angle of incident light and so forth. And distribution of lights emerging from the convex side (emergent angle characteristics) was obtained by calculation for the case where lights having the same distribution as that of lights emerging from a light guide plate in an actual backlight unit enter from the bottom face side of the convex portion. The calculation was performed by assuming that the refractive index of the inside of the convex portion was 1.5, which is the refractive index of a common acrylic resin.

[0057]

Fig. 3 shows a graph representing distribution of emergent lights, which is a result of simulation performed for the convex portion having the shape shown in Fig. 2-2. In the graph, the solid line represents distribution of emergent lights, and the dotted line represents distribution of incident lights. In order to provide favorable front luminance and light scattering property of a certain degree, it is desirable that components of lights emerging with an angle within the range of the front direction ($0 \text{ degree} \pm 30 \text{ degrees}$) should be abundant.

[0058]

Then, in order to find conditions for obtaining emergent light characteristics satisfying such conditions for a rough surface on which multiple convex portions are formed, change of emergent light distribution was simulated while the shape of the convex portions and height thereof was variously changed for a system having a multiple number of the convex portions mentioned above. Specifically, by using, for the convex portion, a constant bottom area, 5 to 6 kind of heights, and about 100 kinds of curve shapes for each height, 500 to 600 kinds in total of shapes of the convex portion were defined, and distribution of emergent lights was simulated for 500 to 600 kinds of samples each having multiple convex portions of a single shape on a plane. The results are shown in the graph of Fig. 4. In the graph, the horizontal axis represents average of slopes of the curved surface (θ_{nv}), and the vertical axis represents energy of emergent lights. In the graph, among the points represented by Δ , \square and \bigcirc , those of the first group 601 represented by Δ indicate energies of emergent lights within the range of 6 degrees about the z axis (henceforth referred to as "emergent lights₆") for

the samples, those of the second group 602 represented by \square indicate energies of emergent lights within the range of 18 degrees about the z axis (henceforth referred to as "emergent lights₁₈") for the samples, and those of the third group 603 represented by \circ indicate energies of emergent lights within the range of 30 degrees about the z axis (henceforth referred to as "emergent lights₃₀") for the samples.

[0059]

From the simulation results shown in Fig. 4, it was found that if the average of slopes of the curved surface (θ_{nv}) was not less than 27 degrees and not more than 70 degrees, preferably not less than 27 degrees and not more than 65 degrees, more preferably not less than 27 degrees and not more than 60 degrees, the ratio of the emergent light ₃₀ increased.

[0060]

Moreover, in the simulation results shown in Fig. 4, there was observed a tendency that the ratio of the emergent light ₃₀ increased as the average of slopes of the curved surface (θ_{nv}) became larger, but when it became further larger exceeding a certain level, the ratio conversely decreased. Therefore, a comprehensive index of convexoconcave profile providing correlation with the emergent light ₃₀ was investigated. As a result, it was found that if a quotient or product of the average of slopes of the curved surface (θ_{nv}) and a ratio of a surface area of the curved surface constituting the rough surface (A2) to an area of an approximately square region on the rough surface (A1, area of the orthogonal projection of the rough surface) ($A_r = A2/A1$, henceforth referred to as "surface area ratio") was used, the relation with the emergent light ₃₀ can be best described. A2 can be

obtained by totaling the areas of planes in a minute triangle shape obtained from height data.

[0061]

Figs. 5 and 6 show graphs representing the simulation data of Fig. 4 by using the indexes of θ_{nv} and A_r . Fig. 5 represents change of the emergent light energy with change of a value obtained by dividing the average of slopes of the curved surface (θ_{nv}) with the surface area ratio (A_r) plotted in the horizontal axis, and Fig. 6 represents change of the emergent light energy with change of a value obtained by multiplying the average of slopes of the curved surface (θ_{nv}) with the surface area ratio (A_r) plotted in the horizontal axis.

[0062]

From the results shown in Figs. 5 and 6, it was found that when the value obtained by dividing the average of slopes of the curved surface (θ_{nv}) with the surface area ratio (A_r) (quotient) was not less than 22, or when the value obtained by multiplying the average of slopes of the curved surface (θ_{nv}) with the surface area ratio (A_r) (product) was not less than 30 and not more than 140, the energy of emergent lights having an emergent angle of 30 degrees or less sharply increased. That is, it can be seen that when either one of the following conditions (equation (1) or equation (2)) is satisfied, a light control film exhibiting high front luminance and moderate light diffusion property is constituted.

$$\theta_{nv} \div A_r \geq 22 \quad (1)$$

$$30 \leq \theta_{nv} \times A_r \leq 140 \quad (2)$$

[0063]

The value obtained by dividing the average of slopes of the curved surface (θ_{nv}) with the surface area ratio (A_r) in the formula (1) is more preferably not less than 25. As

for the lower limit of the product of the average of slopes of the curved surface (θ_{nv}) and the surface area ratio (A_r) in the formula (2) is more preferably not less than 35, and as for the upper limit, the product is more preferably not more than 130.

[0064]

Such conditions must be satisfied at substantially any position. The expression "substantially any position" is used to mean that it is sufficient that the conditions should be satisfied at almost all observation positions when observation is performed at multiple measurement positions for a certain specific light control film, and it include a case that the conditions are not satisfied at one or two positions.

[0065]

In the aforementioned simulation for finding the conditions which the rough surface of the present invention must satisfy, the convex portions were assumed to consist of a material having a refractive index of 1.5. However, materials generally used for optical films can be used for the patterned layer of the light control film of the present invention, and the refractive index thereof is not limited to 1.5. In order to generalize the conditions in consideration of the refractive index n , the aforementioned simulation was repeated with changing the refractive index within a predetermined range. As a result, it was found that when the average of slopes of the curved surface (θ_{nv}) is not less than $(59 - 20n)$ degrees and not more than 70 degrees, the aforementioned effect could be obtained.

[0066]

If the aforementioned formulas (1) and (2) are similarly generalized in consideration of the refractive index n , they can be represented as the following formulas

(3) and (4).

$$\theta_{nv} \div A_r \times n^2 \geq 35 \quad (3)$$

$$60 \leq \theta_{nv} \times A_r \times n^2 \leq 350 \quad (4)$$

[0067]

The value of the left side of the formula (3) is more preferably not less than 40. As for the lower limit of the value of the center portion of the formula (4), it is not less than more preferably 70, and as for the upper limit, the value is more preferably not more than 340. By designing the convexo-concave profile in consideration of the refractive index of the material constituting the convexoconcaves as described above, the luminance for the front direction can be more improved.

[0068]

Another comprehensive index of the convexo-concave profile that could provide correlation with the emergent light θ_{30} was further investigated on the basis of the results of the aforementioned simulation, and as a result, it was found that if a numerical value A_{sk} representing an index of asymmetry of a probability density function for the height direction obtained from all the surface height data used for obtaining the average of slopes of the curved surface, or a numerical value A_{ku} representing an index of sharpness of the probability density function for the height direction obtained from all the surface height data is used, the correlation with the emergent light θ_{30} could be described better.

[0069]

Figs. 7 and 8 show graphs representing the simulation data of Fig. 4 by using the index of θ_{nv} , and the both represent change of the emergent light energy with change of the average of slopes of the curved surface (θ_{nv}) plotted in the horizontal axis. In Fig. 7, the points of

"●" 704 represent the data of the samples showing a value of 1.2 or less as an absolute value of A_{sk} represented by the aforementioned formula (5). In Fig. 8, the points of "●" 804 represent the data of the samples showing a value of not less than 1.5 and not more than 5.0 as A_{ku} represented by the aforementioned formula (6).

[0070]

From the results shown in Figs. 7 and 8, it was found that the energy of emergent lights having an projected angle of 30 degrees or less tended to sharply increase when the average of slopes of the curved surface (θ_{nv}) was not less than 27 degrees and not more than 70 degrees, whereas the rate of the emergent light $_{30}$ did not become high in some cases even if the average of slopes of the curved surface (θ_{nv}) was within the aforementioned range (the points of "○" 703 in Fig. 7, and the points of "○" 803 in Fig. 8). However, it was found that if only the results where the absolute value of A_{sk} represented by the aforementioned formula (5) was not more than 1.2 (points of "●" 704 in Fig. 7) were observed, the rate of the emergent light $_{30}$ was always high. Moreover, it was found that if only the results where A_{ku} represented by the aforementioned formula (6) was not less than 1.5 and not more than 5.0 (points of "●" 804 in Fig. 6) were observed, the rate of the emergent light $_{30}$ was always high.

[0071]

When the average of slopes of the curved surface (θ_{nv}) is not less than 27 degrees and not more than 70 degrees, preferably not less than 27 degrees and not more than 65 degrees, more preferably not less than 27 degrees and not more than 60 degrees, and the absolute value of A_{sk} represented by the formula (5) is not more than 1.2, preferably not more than 1.1, or A_{ku} represented by the

formula (6) is not less than 1.5 and not more than 5.0, preferably not less than 1.5 and not more than 4.5, particularly superior effect can be obtained.

[0072]

Such conditions must be satisfied at substantially any position. The expression "substantially any position" is used to mean that it is sufficient that the conditions should be satisfied at almost all observation positions when observation is performed at multiple measurement positions for a certain specific light control film, and it include a case that the conditions are not satisfied at one or two positions.

[0073]

In the aforementioned simulation for finding the conditions which the rough surface of the present invention must satisfy, the convex portions were assumed to consist of a material having a refractive index of 1.5. However, materials generally used for optical films can be used for the patterned layer of the light control film of the present invention, and the refractive index thereof is not limited to 1.5. If the condition is generalized in consideration of the refractive index n , when the average of slopes of the curved surface (θ_{nv}) is not less than $(59 - 20n)$ degrees and not more than 70 degrees, the aforementioned effect can be obtained.

[0074]

By designing the convexo-concave profile in consideration of the refractive index of the material constituting the patterned layer as described above, the luminance for the front direction can be further improved.

[0075]

Figs. 9 and 10 show graphs representing the simulation data of Fig. 4 by using the surface area ratio

(A_r), and both the graphs represent change of the emergent light energy with change of the surface area ratio (A_r) plotted in the horizontal axis. In Fig. 9, the points of "●" 904 represent the data of the samples showing a value not more than 1.2 as an absolute value of A_{sk} represented by the aforementioned formula (5). In Fig. 10, the points of "●" 1004 represent the data of the samples showing a value not less than 1.5 and not more than 5.0 as A_{ku} represented by the aforementioned formula (6).

[0076]

From the results shown in Figs. 9 and 10, it was found that the energy of emergent lights of an emergent angle of 30 degrees or less tended to sharply increase when the surface area ratio (A_r) is not less than 1.2 and not more than 2.5, whereas the rate of the emergent light $_{30}$ did not become high in some cases even if the surface area ratio (A_r) was within the aforementioned range (the points of "○" 903 in Fig. 9, and the points of "○" 1003 in Fig. 10). However, it was found that if only the results where the absolute value of A_{sk} represented by the aforementioned formula (5) was not more than 1.2 (points of "●" 904 in Fig. 9) were observed, the rate of the emergent light $_{30}$ was always high. Moreover, it was found that if only the results where A_{ku} represented by the aforementioned formula (6) was not less than 1.5 and not more than 5.0 (points of "●" 1004 in Fig. 10), the rate of the emergent light $_{30}$ was always high.

[0077]

When this surface area ratio (A_r) is not less than 1.2 and not more than 2.5, preferably not less than 1.3 and not more than 2.4, more preferably not less than 1.4 and not more than 2.3, and the absolute value of A_{sk} represented by the formula (5) is not more than 1.2,

preferably not more than 1.1, or A_{ku} represented by the formula (6) is not less than 1.5 and not more than 5.0, preferably not less than 1.5 and not more than 4.5, particularly superior effect can be obtained.

[0078]

Such conditions must be satisfied at substantially any position. The expression "substantially any position" is used to mean that it is sufficient that the conditions should be satisfied at almost all observation positions when observation is performed at multiple measurement positions for a certain specific light control film, and it include a case that the conditions are not satisfied at one or two positions.

[0079]

In the aforementioned simulation for finding the conditions which the rough surface of the present invention must satisfy, the convex portions were assumed to consist of a material having a refractive index of 1.5. However, materials generally used for optical films can be used for the patterned layer of the light control film of the present invention, and the refractive index thereof is not limited to 1.5. If the conditions are generalized in consideration of the refractive index n , the aforementioned effect can be obtained when the surface area ratio (A_r) is not less than $(2 - 0.5n)$ and not more than 2.5.

[0080]

By designing the profile of the rough surface in consideration of the refractive index of the material constituting the patterned layer as described above, the luminance for the front direction can be more improved.

[0081]

By designing the rough surface so that it should satisfy the aforementioned conditions, the light control

film of the present invention can exhibit high front luminance, and have a light diffusing property of a certain degree. The light control film of the present invention having such characteristics is disposed, for example, directly on a light guide plate of a backlight unit of the edge light type, or via a light diffusing material on a light source of a backlight unit of the direct type, and used as a film for controlling the direction of emergent lights of the backlight unit.

[0082]

So long as "the average of slopes of the curved surface (θ_{nv}) of the rough surface" or "the surface area ratio (A_r)" of the light control film of the present invention satisfies any one of the aforementioned conditions 1 to 12, the shape and arrangement of the convex portions are not particularly limited. That is, the convex portions and concave portions may be randomly or regularly arranged. However, if a random arrangement is used, generation of an interference pattern can be easily prevented even if another member having a regular pattern is used in combination. Individual convex portions and concave portions may have the same shape or different shapes, and they may be arranged so that they should overlap with one another, or a part or all of the convex portions and concave portions should overlap with one another. The height of the convex portions and depth of the concave portions are both about 3 to 100 μm , and arrangement density of the convex portions or the concave portions is preferably about 10 to 200,000 portions/ mm^2 . A typical rough surface of the light control film satisfying the aforementioned conditions is shown in Fig. 11.

[0083]

Hereafter, specific configurations for producing the

light control film having the aforementioned rough surface will be explained.

[0084]

As the material constituting the substrate 11 and the patterned layer 12 of the light control film 10 of the present invention, materials generally used for optical films can be used. Specifically, the material for the substrate 11 is not especially limited so long as a material exhibiting favorable light transmission property is chosen, and plastic films such as those of polyethylene terephthalate, polybutylene terephthalate, polyethylene naphthalate, polycarbonate, polyethylene, polypropylene, polystyrene, triacetyl cellulose, polyacrylate, polyvinyl chloride, and so forth can be used.

[0085]

The material for constituting the patterned layer 12 is not also especially limited so long as a material exhibiting favorable light transmission property is chosen, and glass, polymer resins, and so forth can be used. Examples of the glass include oxide glass such as silicate glass, phosphate glass, and borate glass. Examples of the polymer resins include thermoplastic resins, thermosetting resins, and ionizing radiation curable resins such as polyester resins, acrylic resins, acrylic urethane resins, polyester acrylate resins, polyurethane acrylate resins, epoxy acrylate resins, urethane resins, epoxy resins, polycarbonate resins, cellulose resins, acetal resins, vinyl resins, polyethylene resins, polystyrene resins, polypropylene resins, polyamide resins, polyimide resins, melamine resins, phenol resins, silicone resins, and fluorocarbon resins, and so forth.

[0086]

Among these materials, polymer resins are preferred

in view of workability and handling property, and those having a refractive index (JIS K7142:1996) of about 1.3 to 1.7 are especially preferably used. Even if a material having a refractive index n out of the aforementioned range is used as a material constituting the patterned layer, favorable luminance can be realized so long as the condition 1, 3, 5, 7, 9 or 11 is satisfied. However, by using a material having a refractive index within such a range, high luminance can be obtained. In particular, by designing the rough surface so that it should satisfy the condition 2, 4, 6, 8, 10 or 12 depending on the refractive index of the material, front luminance can be further improved.

[0087]

Although the patterned layer 12 may comprise light diffusing agents such as beads of organic materials and inorganic pigments, like general light diffusive sheets, they are not indispensable. The light control film of the present invention can exert light diffusing effect to a certain degree by the rough surface itself, even if it does not comprise light diffusing agents. If light diffusing agents are not used, other members are not damaged by light diffusing agents, or light diffusing agents do not separate and fall to generate dusts.

[0088]

As the method for forming the patterned layer 12, 1) a method of using an embossing roller, 2) a method of using an etching treatment, and 3) a method of using molding with a mold can be employed. However, a production method of using a mold is preferred, because it enables production of light control films having a predetermined patterned layer with good reproducibility. Specifically, the production can be attained by preparing a mold having a profile

complementary to that of the rough surface, casting a material constituting the patterned layer such as polymer resins into the mold, curing the material, and taking out the cured material from the mold. When a substrate is used, the production can be attained by casting a polymer resin or the like into the mold, superimposing a transparent substrate thereon, curing the polymer resin or the like, and taking out the cured material together with the transparent substrate from the mold.

[0089]

Although the method of forming a profile complementary to the rough surface in the mold is not particularly limited, the following method can be employed. For example, convex portions having a specific shape are formed on a plate so that the arrangement density of the portions should be several thousands portions/mm² by a laser microprocessing technique, and this plate is used as a male mold to prepare a mold for molding (female mold). The convex portions having a specific shape means such convex portions that when height data thereof are measured with equal intervals of a length that allows correct reflection of the shape of one whole convex portion (1.0 μ m or shorter), the convex portions should satisfy the condition 1 or 3. Alternatively, resin plates having a convex-concave layer are prepared by curing a resin containing particles of a predetermined particles size dispersed therein, the surfaces of the patterned layers are measured by using a surface profiler to choose a resin plate satisfying the aforementioned conditions, and a mold for molding (female mold) is prepared by using the chosen plate as a male mold.

[0090]

Although the surface of the light control film

opposite to the rough surface may be smooth, it may be subjected to a fine matting treatment in order to prevent generation of Newton rings when the film is brought into contact with a light guide plate or resin plate, or an antireflection treatment in order to improve light transmittance.

[0091]

Moreover, in order to obtain favorable front luminance, as an optical characteristic of the light control film, the film desirably has a haze of 60% or more, preferably 70% or more. The haze referred to herein is a value of the haze defined in JIS K7136:2000, and is a value obtained in accordance with the equation: Haze (%) = $[(\tau_4/\tau_2) - \tau_3(\tau_2/\tau_1)] \times 100$ (τ_1 : flux of incident light, τ_2 : total light flux transmitted through a test piece, τ_3 : light flux diffused in a unit, τ_4 : light flux diffused in the unit and test piece).

[0092]

Although the total thickness of the light control film is not particularly limited, it is usually about 20 to 300 μm .

[0093]

The light control film of the present invention explained above is mainly used as a member of a backlight constituting a liquid crystal display, illumination signboard, and so forth.

[0094]

Hereafter, the backlight of the present invention will be explained. The backlight of the present invention consists at least of a light control film and a light source. As the light control film, the aforementioned light control film is used. Although the direction of the light control film arranged in the backlight is not

particularly limited, it is preferably used so that the rough surface should serve as a light emergent surface side. For the backlight, a configuration called edge light type or direct type is preferably employed.

[0095]

A backlight of the edge light type consists of a light guide plate, a light source disposed on at least one end of the light guide plate, a light control film disposed on the light emergent surface side of the light guide plate, and so forth. The light control film is preferably used so that the rough surface should serve as the light emergent surface. Further, a prism sheet is preferably used between the light guide plate and the light control film. With such a configuration, a backlight unit exhibiting superior balance of front luminance and a view angle and not exhibiting glare, which is a problem peculiar to a prism sheet, can be provided.

[0096]

The light guide plate has a substantially plate-like shape at least one of which sides serves as a light incident surface and one of which surfaces perpendicular to the side serves as a light emergent surface, and mainly consists of a matrix resin selected from highly transparent resins such as polymethyl methacrylate. Resin particles having a refractive index different from that of the matrix resin may be added as required. Each surface of the light guide plate may not be a uniform plane, but has a complicated surface profile, or may be subjected to diffusion printing for a dot pattern or the like.

[0097]

The light source is disposed end of the light guide plate, and a cold-cathode tube is mainly used. Examples of the shape of the light source include a linear shape, L-

shape, and so forth.

[0098]

Besides the aforementioned light control film, light guide plate, and light source, the backlight of the edge light type may be equipped with a light reflector, a polarization film, an electromagnetic interference shield film etc. depending on the purpose.

[0099]

One embodiment of the backlight of the edge light type according to the present invention is shown in Fig. 12. This backlight 140 has a configuration that light sources 142 are provided on the both sides of a light guide plate 141, and a light control film 143 is placed on the upside of the light guide plate 141 so that a rough surface should be exposed to the outside. The light sources 142 are covered with light source rear reflectors 144 except for the parts facing the light guide plate 141 so that lights from the light source should efficiently enter into the light guide plate 141. Moreover, a light reflector 146 stored in a chassis 145 is provided under the light guide plate 141. By this configuration, lights projected on the side of the light guide plate 141 opposite to the projecting side are returned into the light guide plate 141 again to increase lights emerging from the projection surface of the light guide plate 141.

[0100]

A backlight of the direct type consists of a light control film, and a light diffusive material and a light source disposed in this order on a surface of the light control film opposite to the light emergent surface, and so forth. The light control film is preferably used so that the rough surface should serve as the light emergent surface. Moreover, a prism sheet is preferably used

between the light diffusing material and the light control film. With such a configuration, a backlight unit exhibiting superior balance of front luminance and view angle and not exhibiting glare, which is a problem peculiar to a prism sheet, can be provided.

[0101]

The light diffusive material is for erasing a pattern of the light source, and a milky resin plate, a transparent substrate on which a dot pattern is formed on a portion corresponding to the light source (lighting curtain) as well as a so-called light diffusive film having a convexo-concave light diffusing layer on a transparent film, and so forth can be used individually or in a suitable combination.

[0102]

As the light source, a cold-cathode tube is mainly used. Examples of the shape of the light source include a linear shape, L-shape, and so forth. Besides the aforementioned light control film, light diffusing material, and light source, the backlight of the direct type may be equipped with a light reflector, a polarization film, an electromagnetic wave shield film, etc. depending on the purpose.

[0103]

One embodiment of the backlight of the direct type according to the present invention is shown in Fig. 13. This backlight 150 has a configuration that plural light sources 152 are provided above a light reflector 156 stored in a chassis 155, and a light control film 153 is placed thereon via a light diffusive material 157 as shown in the drawing.

[0104]

Because the backlight of the present invention utilizes a light control film having a specific rough

surface as a light control film that controls direction of lights emerging from a light source or a light guide plate, it can improve front luminance compared with conventional backlights, and suffers from the problem of glare and generation of scratches in less degrees compared with the case of using a prism sheet alone.

[Examples]

[0105]

Hereafter, the present invention will be further explained with reference to examples.

[0106]

[Examples 1 to 4]

Four kinds of molds (1) to (4) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, an ultraviolet curing resin having a refractive index of 1.50 was poured into the molds (1) to (3), and a silicone resin having a refractive index of 1.40 was poured into the mold (4). Subsequently, the poured resins were cured, and then taken out from the molds to obtain light control films (1) to (4) having a size of 23 cm (for the direction perpendicular to the light source) x 31 cm (for the direction parallel to the light source) (light control film of Examples 1 to 4).

[0107]

Then, height data of the rough surfaces (light emergent surfaces) of the light control films (1) to (4) were measured by using a laser microscope (VK-9500, KEYENCE CORP.) with an objective lens of magnification x 50. The measurement interval in the plane was about 0.26 μm . Since one field of the objective lens of magnification x 50 is 270 μm x 202 μm , an automatic connecting function was used to obtain surface height data of a region of 1 mm x 1 mm. The measurement was performed at arbitrary 5 positions on each light control film, and averages of slopes of the curved surfaces to base planes (θ_{nv} , unit is degree) were calculated by using these surface height data. The results obtained for the light control films (1) to (4) are shown in Table 1. Further, by using a turbidimeter (NDH2000, Nippon Denshoku), hazes of the light control films (1) to

(4) were measured according to JIS K7136:2000. The measurement results are also shown in Table 1.

[0108]

[Table 1]

| | θ_{nv} (degree) | haze (%) |
|-----------|---------------------------|-------------|
| Example 1 | 43.0 | 82.7 |
| | 43.0 | |
| | 43.7 | |
| | 41.4 | |
| | 41.9 | |
| Example 2 | 34.1 | 82.6 |
| | 35.6 | |
| | 33.8 | |
| | 34.8 | |
| | 32.7 | |
| Example 3 | 29.6 | 79.1 |
| | 28.2 | |
| | 28.4 | |
| | 28.3 | |
| | 31.0 | |
| Example 4 | 33.4 | 79.7 |
| | 34.4 | |
| | 32.8 | |
| | 34.9 | |
| | 33.7 | |

[0109]

As seen from the results shown in Table 1, the averages of slopes of the curved surfaces of the light control films of Examples 1 to 4 were not less than 27 degrees and not more than 70 degrees at all the measurement points. Moreover, all the light control films of Examples 1 to 4 had a haze of 70% or higher, and thus satisfied the optical characteristics required for obtaining favorable front luminance.

[0110]

Then, the light control films (1) to (4) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (1) to (4) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (1) to (4) are shown in Table 2 (unit is "cd/m²").

[0111]

[Table 2]

| | | luminance (c d/m ²) | | | |
|-------------------------|-----------------|---------------------------------|-----------|-----------|-----------|
| | | Example 1 | Example 2 | Example 3 | Example 4 |
| parallel direction | left 45 degree | 1 0 5 0 | 1 1 3 0 | 1 1 5 0 | 1 1 4 0 |
| | left 30 degree | 2 1 0 0 | 1 7 3 0 | 1 6 3 0 | 1 6 8 0 |
| | 0 degree | 2 3 0 0 | 1 8 1 0 | 1 6 8 0 | 1 7 4 0 |
| | right 30 degree | 2 0 7 0 | 1 7 1 0 | 1 6 2 0 | 1 6 6 0 |
| | right 45 degree | 1 0 6 0 | 1 1 3 0 | 1 1 5 0 | 1 1 4 0 |
| perpendicular direction | up 45 degree | 1 0 4 0 | 1 2 4 0 | 1 2 9 0 | 1 2 7 0 |
| | up 30 degree | 2 3 7 0 | 1 9 5 0 | 1 8 4 0 | 1 8 9 0 |
| | 0 degree | 2 3 0 0 | 1 8 1 0 | 1 6 8 0 | 1 7 4 0 |
| | down 30 degree | 2 3 5 0 | 1 9 4 0 | 1 8 3 0 | 1 8 8 0 |
| | down 45 degree | 1 0 1 0 | 1 2 3 0 | 1 2 9 0 | 1 2 6 0 |

[0112]

It was demonstrated by the results shown in Table 2 that, for the light control films of Examples 1 to 4, only by incorporating one sheet of light control film into the backlight unit, the luminance for emergent angles of 30 degrees or less could be increased, and thus strong emergent lights could be obtained for the front direction.

[0113]

[Examples 5 to 8]

Four kinds of molds (5) to (8) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, an ultraviolet curing resin having a refractive index of 1.50 was poured

into the molds (5) to (7), and a silicone resin having a refractive index of 1.40 was poured into the mold (8). Subsequently, the poured resins were cured, and then taken out from the molds to obtain light control films (5) to (8) having a size of 23 cm x 31 cm (light control films of Examples 5 to 8).

[0114]

Then, height data of the rough surfaces (light emergent surfaces) of the light control films (5) to (8) were measured in the same manner as that used in Examples 1 to 4. The measurement was performed at arbitrary 5 positions on each light control film, and averages of slopes to base planes of the curved surfaces (θ_{nv} , unit is degree) were calculated by using the obtained surface height data. Further, surface areas of the rough surfaces (A_2) were obtained from the same surface height data, the ratios thereof to the orthogonal projections of the measured rough surfaces (A_1) ($A_r = A_2/A_1$) were calculated, and products or quotients were obtained by using the averages of slopes of the curved surface (θ_{nv}), and the surface area ratios (A_r). The results obtained for the light control films (5) to (8) are shown in Table 3 (unit of slope is "degree"). Further, by using a turbidimeter (NDH2000, Nippon Denshoku), hazes of the light control films (5) to (8) were measured according to JIS K7136:2000. The measurement results are also shown in Table 3.

[0115]

[Table 3]

| | θ_{nv} (degree) | A_r | $\theta_{nv} \div A_r$ | $\theta_{nv} \times A_r$ | haze (%) |
|-----------|---------------------------|-------|------------------------|--------------------------|-------------|
| Example 5 | 42.6 | 1.552 | 27.4 | 66.1 | 82.7 |
| | 42.2 | 1.573 | 26.9 | 66.4 | |
| | 41.1 | 1.613 | 25.5 | 66.3 | |
| | 43.1 | 1.500 | 28.8 | 64.7 | |
| | 43.6 | 1.594 | 27.3 | 69.4 | |
| Example 6 | 50.9 | 2.080 | 24.5 | 105.9 | 82.6 |
| | 52.4 | 2.046 | 25.6 | 107.2 | |
| | 51.7 | 2.168 | 23.9 | 112.2 | |
| | 53.1 | 2.032 | 26.2 | 108.0 | |
| | 48.9 | 2.022 | 24.2 | 98.9 | |
| Example 7 | 36.5 | 1.389 | 26.3 | 50.7 | 82.0 |
| | 36.7 | 1.393 | 26.4 | 51.2 | |
| | 35.0 | 1.399 | 25.0 | 48.9 | |
| | 35.7 | 1.427 | 25.0 | 50.9 | |
| | 36.9 | 1.414 | 26.1 | 52.2 | |
| Example 8 | 44.0 | 1.735 | 25.4 | 76.3 | 82.1 |
| | 44.8 | 1.809 | 24.7 | 81.0 | |
| | 44.6 | 1.713 | 26.1 | 76.5 | |
| | 42.0 | 1.732 | 24.2 | 72.7 | |
| | 43.8 | 1.749 | 25.1 | 76.7 | |

[0116]

As shown in Table 3, in the light control films of Examples 5 to 8, fluctuation of the average of slopes of

the curved surface and the surface area ratio was small at all the measurement points, and thus the films had a uniform roughness characteristic as the whole films. Moreover, all the light control films of Examples 5 to 8 had a haze of 70% or higher, and thus satisfied the optical characteristics required for obtaining favorable front luminance.

[0117]

Then, the light control films (5) to (8) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (5) to (8) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (5) to (8) are shown in Table 4 (unit is "cd/m²").

[0118]

[Table 4]

| | | luminance (c d / m ²) | | | |
|-------------------------|-----------------|-----------------------------------|-----------|-----------|-----------|
| | | Example 5 | Example 6 | Example 7 | Example 8 |
| parallel direction | left 45 degree | 1 0 6 0 | 1 1 0 0 | 1 1 3 0 | 1 1 1 0 |
| | left 30 degree | 2 0 4 0 | 1 8 5 0 | 1 7 1 0 | 1 8 0 0 |
| | 0 degree | 2 2 2 0 | 1 9 7 0 | 1 7 8 0 | 1 9 0 0 |
| | right 30 degree | 2 0 2 0 | 1 8 3 0 | 1 6 9 0 | 1 7 8 0 |
| | right 45 degree | 1 0 8 0 | 1 1 1 0 | 1 1 4 0 | 1 1 2 0 |
| perpendicular direction | up 45 degree | 1 0 7 0 | 1 1 7 0 | 1 2 5 0 | 1 2 0 0 |
| | up 30 degree | 2 3 1 0 | 2 0 9 0 | 1 9 3 0 | 2 0 3 0 |
| | 0 degree | 2 2 2 0 | 1 9 7 0 | 1 7 8 0 | 1 9 0 0 |
| | down 30 degree | 2 2 8 0 | 2 0 7 0 | 1 9 1 0 | 2 0 1 0 |
| | down 45 degree | 1 0 4 0 | 1 1 6 0 | 1 2 4 0 | 1 1 9 0 |

[0119]

It was demonstrated by the results shown in Table 4 that, for the light control films of Examples 5 to 8, only by incorporating one sheet of light control film into the backlight unit, the luminance for emergent angles of 30 degrees or less could be increased, and thus strong emergent lights could be obtained for the front direction.

[0120]

[Comparative Examples 1 to 3]

For commercially available light diffusive sheets (Comparative Examples 1 to 3), surface profiles of rough surfaces (light emergent surfaces) were measured at 5

points on each film in the same manner as that used in the examples, and averages of slopes of the curved surface (θ_{nv}) were calculated. The results obtained for the light diffusive sheets of Comparative Examples 1 to 3 are shown in Table 5 in order.

[0121]

[Table 5]

| | θ_{nv} (degree) | haze (%) |
|--------------------------|---------------------------|-------------|
| Comparative Example 1 | 25.2 | 89.2 |
| | 25.3 | |
| | 25.0 | |
| | 26.2 | |
| | 26.0 | |
| Comparative Example 2 | 16.8 | 85.7 |
| | 16.3 | |
| | 17.2 | |
| | 16.7 | |
| | 16.1 | |
| Comparative Example 3 | 10.7 | 65.5 |
| | 10.3 | |
| | 10.6 | |
| | 10.7 | |
| | 11.2 | |

[0122]

As seen from the results shown in Table 5, all the light diffusive sheets of Comparative Examples 1 to 3 were those that could not provide an average of slopes of the curved surface (θ_{nv}) not less than 27 degrees and not more than 70 degrees at all the measurement points.

[0123]

Then, the light diffusive sheets of Comparative Examples 1 to 3 were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light diffusive sheets of Comparative Examples 1 to 3 were each disposed on a light guide plate so that the rough surface of the light diffusive sheet should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results are shown in Table 6.

[0124]

[Table 6]

| | | luminance (c d / m ²) | | |
|-------------------------|--------------------|-----------------------------------|--------------------------|--------------------------|
| | | Comparative Example 1 | Comparative Example 2 | Comparative Example 3 |
| parallel direction | left 45 degree | 1 1 7 0 | 1 3 1 0 | 1 2 5 0 |
| | left 30 degree | 1 5 4 0 | 1 3 1 0 | 1 1 7 0 |
| | 0 degree | 1 5 6 0 | 1 2 2 0 | 1 0 7 0 |
| | right 30 degree | 1 5 1 0 | 1 3 1 0 | 1 1 7 0 |
| | right 45 degree | 1 1 7 0 | 1 3 1 0 | 1 2 4 0 |
| perpendicular direction | up 45 degree | 1 3 4 0 | 1 6 2 0 | 1 5 4 0 |
| | up 30 degree | 1 7 4 0 | 1 5 0 0 | 1 3 2 0 |
| | 0 degree | 1 5 6 0 | 1 2 2 0 | 1 0 7 0 |
| | down 30 degree | 1 7 0 0 | 1 4 7 0 | 1 3 7 0 |
| | down 45 degree | 1 3 4 0 | 1 5 8 0 | 1 6 0 0 |

[0125]

As seen from the results shown in Table 6, when the conventional light diffusive sheets were incorporated into the backlight unit, favorable front luminance could not be obtained.

[0126]

As clearly seen from the results of the aforementioned examples, the light control films of the examples were those exhibiting superior front luminance and appropriate light diffusing property, because the rough surfaces thereof were designed to satisfy the specific

configuration. Moreover, by incorporating such light control films into a backlight unit, backlight units exhibiting strong front luminance and not suffering from glare and generation of an interference pattern could be provided.

[0127]

[Examples 9 to 12]

Four kinds of molds (9) to (12) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, an ultraviolet curing resin having a refractive index of 1.50 was poured into the molds (9) to (11), and a silicone resin having a refractive index of 1.40 was poured into the mold (12). Subsequently, the poured resins were cured, and then taken out from the molds to obtain light control films (9) to (12) having a size of 23 cm (for the direction perpendicular to the light source) x 31 cm (for the direction parallel to the light source) (light control film of Examples 9 to 12).

[0128]

Then, height data of the rough surfaces (light emergent surfaces) of the light control films (9) to (12) were measured by using a laser microscope (VK-9500, KEYENCE CORP.) with an objective lens of magnification x 50. The measurement interval in the plane was about 0.26 μm . Since one field of the objective lens of magnification x 50 is 270 μm x 202 μm , an automatic coupling function was used to obtain surface height data of a region of 1 mm x 1 mm. The measurement was performed at arbitrary 5 positions on each light control film, and averages of slopes of the curved surfaces to base planes (θ_{nv}) were calculated by using these surface height data. Further, A_{sk} was calculated in accordance with the aforementioned formula (5) by using the

same surface height data. The results obtained for the light control films (9) to (12) are shown in Table 1 (unit of slope is "degree"). Further, by using a turbidimeter (NDH2000, Nippon Denshoku), hazes of the light control films (9) to (12) were measured according to JIS K7136:2000. The measurement results are also shown in Table 1.

[0129]

[Table 7]

| | θ_{nv} (degree) | $ A_{sk} $ | haze (%) |
|------------|---------------------------|------------|-------------|
| Example 9 | 42.0 | 0.661 | 82.5 |
| | 43.8 | 0.655 | |
| | 41.0 | 0.644 | |
| | 40.9 | 0.652 | |
| | 41.0 | 0.631 | |
| Example 10 | 34.1 | 0.661 | 82.6 |
| | 35.2 | 0.667 | |
| | 35.6 | 0.683 | |
| | 35.6 | 0.671 | |
| | 33.9 | 0.654 | |
| Example 11 | 29.6 | 0.010 | 79.1 |
| | 28.2 | 0.038 | |
| | 28.6 | 0.104 | |
| | 30.5 | 0.098 | |
| | 29.7 | 0.103 | |
| Example 12 | 36.5 | 0.366 | 82.0 |
| | 34.9 | 0.369 | |
| | 35.9 | 0.368 | |
| | 35.7 | 0.351 | |
| | 38.1 | 0.370 | |

[0130]

As seen from the results shown in Table 7, the averages of slopes of the curved surfaces (θ_{nv}) of the light control films of Examples 9 to 12 were not less than 27 degrees and not more than 70 degrees at all the measurement points. Further, all the absolute values of A_{sk} were not more than 1.2. Moreover, all the light control films of Examples 9 to 12 had a haze of 70% or higher, and thus satisfied the optical characteristics required for obtaining favorable front luminance.

[0131]

Then, the light control films (9) to (12) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (9) to (12) were each disposed on a light guide plate so that the rough surfaces should serve as the light emergent surfaces, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (9) to (12) are shown in Table 8 (unit is "cd/m²").

[0132]

[Table 8]

| | | luminance (cd/m ²) | | | |
|-------------------------|-----------------|--------------------------------|------------|------------|------------|
| | | Example 9 | Example 10 | Example 11 | Example 12 |
| parallel direction | left 45 degree | 1 0 4 0 | 1 1 2 0 | 1 1 5 0 | 1 1 3 0 |
| | left 30 degree | 1 9 6 0 | 1 7 4 0 | 1 6 5 0 | 1 7 2 0 |
| | 0 degree | 2 1 1 0 | 1 8 1 0 | 1 6 8 0 | 1 7 8 0 |
| | right 30 degree | 1 9 3 0 | 1 7 2 0 | 1 6 3 0 | 1 7 0 0 |
| | right 45 degree | 1 0 6 0 | 1 1 3 0 | 1 1 5 0 | 1 1 3 0 |
| perpendicular direction | up 45 degree | 9 0 3 | 1 1 5 0 | 1 2 5 0 | 1 1 7 0 |
| | up 30 degree | 2 0 7 0 | 1 8 7 0 | 1 7 9 0 | 1 8 5 0 |
| | 0 degree | 2 1 1 0 | 1 8 1 0 | 1 6 8 0 | 1 7 8 0 |
| | down 30 degree | 2 0 6 0 | 1 8 7 0 | 1 8 0 0 | 1 8 6 0 |
| | down 45 degree | 9 4 8 | 1 1 7 0 | 1 2 7 0 | 1 2 0 0 |

[0133]

It was demonstrated by the results shown in Table 8 that, for the light control films of Examples 9 to 12, only by incorporating one sheet of light control film into the backlight unit, the luminance for emergent angles of 30 degrees or less could be increased, and thus strong emergent lights could be obtained for the front direction.

[0134]

[Examples 13 to 16]

Four kinds of molds (13) to (16) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, an ultraviolet curing resin having a refractive index of 1.50 was poured into the molds (13) to (15), and a silicone resin having a refractive index of 1.40 was poured into the mold (16). Subsequently, the poured resins were cured, and

then taken out from the molds to obtain light control films (13) to (16) having a size of 23 cm x 31 cm.

[0135]

Then, height data of the rough surfaces (light emergent surfaces) of the light control films (13) to (16) were measured in the same manner as that used in Examples 9 to 12. The measurement was performed at arbitrary 5 positions on each light control film, and averages of slopes of the curved surfaces to base planes (θ_{nv}) were calculated by using the obtained surface height data. Further, A_{ku} was calculated in accordance with the aforementioned formula (6) by using the same surface height data. The results obtained for the light control films (13) to (16) are shown in Table 9 (unit of slope is "degree"). Further, by using a turbidimeter (NDH2000, Nippon Denshoku), hazes of the light control films (13) to (16) were measured according to JIS K7136:2000. The measurement results are also shown in Table 9.

[0136]

[Table 9]

| | θ_{nv} (degree) | A_{ku} | haze (%) |
|------------|---------------------------|----------|-------------|
| Example 13 | 49.6 | 2.072 | 82.8 |
| | 48.2 | 2.018 | |
| | 44.9 | 2.151 | |
| | 45.8 | 2.113 | |
| | 46.7 | 2.044 | |
| Example 14 | 40.1 | 4.023 | 76.2 |
| | 41.1 | 3.910 | |
| | 38.2 | 4.005 | |
| | 38.5 | 4.102 | |
| | 38.9 | 4.146 | |
| Example 15 | 34.0 | 2.063 | 82.7 |
| | 35.2 | 2.034 | |
| | 32.8 | 1.990 | |
| | 33.0 | 2.131 | |
| | 34.2 | 2.150 | |
| Example 16 | 41.5 | 1.710 | 82.6 |
| | 42.3 | 1.661 | |
| | 40.4 | 1.723 | |
| | 42.9 | 1.774 | |
| | 43.0 | 1.726 | |

[0137]

As seen from the results shown in Table 9, the averages of slopes of the curved surfaces (θ_{nv}) of the light control films of Examples 13 to 16 were not less than

27 degrees and not more than 70 degrees at all the measurement points. Further, all the values of A_{ku} were not less than 1.5 and not more than 5.0. Moreover, all the light control films of Examples 13 to 16 had a haze of 70% or higher, and thus satisfied the optical characteristics required for obtaining favorable front luminance.

[0138]

Then, the light control films (13) to (16) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (13) to (16) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (13) to (16) are shown in Table 10 (unit is "cd/m²").

[0139]

[Table 10]

| | | luminance (cd/m ²) | | | |
|-------------------------|-----------------|--------------------------------|------------|------------|------------|
| | | Example 13 | Example 14 | Example 15 | Example 16 |
| parallel direction | left 45 degree | 1 0 5 0 | 1 1 3 0 | 1 1 5 0 | 1 1 2 0 |
| | left 30 degree | 1 9 5 0 | 1 6 9 0 | 1 6 3 0 | 1 7 4 0 |
| | 0 degree | 2 1 0 0 | 1 7 4 0 | 1 6 5 0 | 1 8 1 0 |
| | right 30 degree | 1 9 2 0 | 1 6 7 0 | 1 6 1 0 | 1 7 2 0 |
| | right 45 degree | 1 0 6 0 | 1 1 4 0 | 1 1 6 0 | 1 1 3 0 |
| perpendicular direction | up 45 degree | 9 1 1 | 1 2 0 0 | 1 2 7 0 | 1 1 5 0 |
| | up 30 degree | 2 0 7 0 | 1 8 3 0 | 1 7 7 0 | 1 8 7 0 |
| | 0 degree | 2 1 0 0 | 1 7 4 0 | 1 6 5 0 | 1 8 1 0 |
| | down 30 degree | 2 0 5 0 | 1 8 3 0 | 1 7 8 0 | 1 8 8 0 |
| | down 45 degree | 9 5 6 | 1 2 2 0 | 1 3 0 0 | 1 1 7 0 |

[0140]

It was demonstrated by the results shown in Table 10 that, for the light control films of Examples 13 to 16, only by incorporating one sheet of light control film into the backlight unit, the luminance for emergent angles of 30 degrees or less could be increased, and thus strong emergent lights could be obtained for the front direction.

[0141]

[Comparative Examples 4 to 6]

Three kinds of molds (17) to (19) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, and an ultraviolet curing resin having a refractive index of 1.50 was poured into the molds. Subsequently, the poured resin was cured, and then taken out from the molds to obtain light control films (17) to (19) having a size of 23 cm x

31 cm (light control films of Comparative Examples 4 to 6).
[0142]

Then, height data of the rough surfaces (light emergent surfaces) of the light control films (17) to (19) were measured in the same manner as that used in Examples 9 to 12. The measurement was performed at arbitrary 5 positions on each light control film, and averages of slopes of the curved surfaces to base planes (θ_{nv}) were calculated by using the obtained surface height data. Further, A_{sk} was calculated in accordance with the aforementioned formula (5) by using the same surface height data. The results obtained for the light control films (17) to (19) are shown in Table 11 (unit of slope is "degree").

[0143]

[Table 11]

| | θ_{nv} (degree) | $ A_{sk} $ | haze (%) |
|--------------------------|---------------------------|------------|-------------|
| Comparative Example 4 | 33.8 | 1.272 | 81.2 |
| | 33.0 | 1.258 | |
| | 35.5 | 1.286 | |
| | 34.8 | 1.269 | |
| | 32.2 | 1.269 | |
| Comparative Example 5 | 41.5 | 1.479 | 81.3 |
| | 40.2 | 1.435 | |
| | 42.1 | 1.452 | |
| | 40.8 | 1.450 | |
| | 40.2 | 1.456 | |
| Comparative Example 6 | 47.7 | 1.408 | 74.5 |
| | 45.7 | 1.398 | |
| | 50.1 | 1.388 | |
| | 49.8 | 1.429 | |
| | 48.5 | 1.404 | |

[0144]

As seen from the results shown in Table 11, the averages of slopes of the curved surfaces (θ_{nv}) of the light control films (17) to (19) were not less than 27 degrees and not more than 70 degrees at all the measurement points. However, all the values of A_{sk} were more than 1.2.

[0145]

Then, the light control films (17) to (19) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the

light control films (17) to (19) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (17) to (19) are shown in Table 12 (unit is "cd/m²").

[0146]

[Table 12]

| | | luminance (c d / m ²) | | |
|----------------------------|--------------------|-----------------------------------|--------------------------|--------------------------|
| | | Comparative Example 4 | Comparative Example 5 | Comparative Example 6 |
| parallel direction | left 45 degree | 1 2 3 0 | 1 2 1 0 | 1 2 0 0 |
| | left 30 degree | 1 4 2 0 | 1 4 6 0 | 1 5 0 0 |
| | 0 degree | 1 3 7 0 | 1 4 2 0 | 1 4 8 0 |
| | right 30 degree | 1 4 2 0 | 1 4 5 0 | 1 5 0 0 |
| | right 45 degree | 1 2 2 0 | 1 2 1 0 | 1 2 0 0 |
| perpendicular direction | up 45 degree | 1 5 0 0 | 1 4 6 0 | 1 4 2 0 |
| | up 30 degree | 1 5 9 0 | 1 6 2 0 | 1 6 6 0 |
| | 0 degree | 1 3 7 0 | 1 4 2 0 | 1 4 8 0 |
| | down 30 degree | 1 6 0 0 | 1 6 3 0 | 1 6 7 0 |
| | down 45 degree | 1 5 0 0 | 1 4 7 0 | 1 4 2 0 |

[0147]

From the results shown in Table 12, it was found that when the light control films of Comparative Examples 4 to 6 were incorporated into a backlight unit, front luminance was insufficient.

[0148]

[Comparative Examples 7 to 9]

Three kinds of molds (20) to (22) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, and an ultraviolet curing resin having a refractive index of 1.50 was poured into the molds. Subsequently, the poured resin was cured, and then taken out from the molds to obtain light control films (20) to (22) having a size of 23 cm x 31 cm (light control films of Comparative Examples 7 to 9). [0149]

Then, height data of the rough surfaces (light emergent surfaces) of the light control films (20) to (22) were measured in the same manner as that used in Examples 9 to 12. The measurement was performed at arbitrary 5 positions on each light control film, and averages of slopes of the curved surfaces to base planes (θ_{nv}) were calculated by using the obtained surface height data. Further, A_{ku} was calculated in accordance with the aforementioned formula (6) by using the same surface height data. The results obtained for the light control films (20) to (22) are shown in Table 13 (unit of slope is "degree").

[0150]

[Table 13]

| | θ_{nv} (degree) | A_{ku} | haze (%) |
|--------------------------|---------------------------|----------|-------------|
| Comparative Example 7 | 28.3 | 1.312 | 70.3 |
| | 28.8 | 1.258 | |
| | 29.0 | 1.281 | |
| | 27.7 | 1.338 | |
| | 29.2 | 1.361 | |
| Comparative Example 8 | 33.4 | 1.395 | 76.9 |
| | 34.6 | 1.302 | |
| | 33.6 | 1.391 | |
| | 34.8 | 1.400 | |
| | 34.9 | 1.393 | |
| Comparative Example 9 | 38.7 | 7.198 | 70.6 |
| | 37.4 | 7.270 | |
| | 39.6 | 7.165 | |
| | 39.9 | 7.053 | |
| | 38.6 | 7.197 | |

[0151]

As seen from the results shown in Table 13, the averages of slopes of the curved surfaces (θ_{nv}) of the light control films (20) to (22) were not less than 27 degrees and not more than 70 degrees at all the measurement points. However, all the values of A_{ku} were less than 1.5 or more than 5.0.

[0152]

Then, the light control films (20) to (22) were each incorporated into a 15-inch edge light type backlight unit

(one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (20) to (22) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (20) to (22) are shown in Table 14 (unit is "cd/m²").

[0153]

[Table 14]

| | | luminance (c d / m ²) | | |
|----------------------------|--------------------|-----------------------------------|--------------------------|--------------------------|
| | | Comparative Example 7 | Comparative Example 8 | Comparative Example 9 |
| parallel direction | left 45 degree | 1 2 7 0 | 1 2 2 0 | 1 2 4 0 |
| | left 30 degree | 1 3 1 0 | 1 4 5 0 | 1 3 9 0 |
| | 0 degree | 1 2 1 0 | 1 4 0 0 | 1 3 2 0 |
| | right 30 degree | 1 3 1 0 | 1 4 4 0 | 1 3 9 0 |
| | right 45 degree | 1 2 6 0 | 1 2 1 0 | 1 2 3 0 |
| perpendicular direction | up 45 degree | 1 6 3 0 | 1 4 8 0 | 1 5 5 0 |
| | up 30 degree | 1 4 8 0 | 1 6 1 0 | 1 5 5 0 |
| | 0 degree | 1 2 1 0 | 1 4 0 0 | 1 3 2 0 |
| | down 30 degree | 1 5 0 0 | 1 6 2 0 | 1 5 7 0 |
| | down 45 degree | 1 6 2 0 | 1 4 8 0 | 1 5 4 0 |

[0154]

From the results shown in Table 14, it was found that when the light control films of Comparative Examples 7 to 9 were incorporated into a backlight unit, front luminance

was insufficient.

[0155]

[Comparative Examples 10 and 11]

For commercially available light diffusive sheets (Comparative Examples 10 and 11), surface height data of rough surfaces (light emergent surfaces) were measured in the same manner as in Examples at arbitrary 5 positions on each sheet, and averages of slopes of the curved surfaces (θ_{nv}) were obtained. Further, A_{sk} and A_{ku} were calculated in accordance with the aforementioned formulas (5) and (6), respectively, by using the same surface height data. The results obtained for the light diffusive sheets of Comparative Examples 10 and 11 are shown in Table 15.

[0156]

[Table 15]

| | θ_{nv} (degree) | $ A_{sk} $ | A_{ku} |
|---------------------------|---------------------------|------------|----------|
| Comparative Example 10 | 25.3 | 0.131 | 3.321 |
| | 26.3 | 0.134 | 3.282 |
| | 26.3 | 0.128 | 3.409 |
| | 24.8 | 0.125 | 3.259 |
| | 24.2 | 0.135 | 3.353 |
| Comparative Example 11 | 16.8 | 0.730 | 3.661 |
| | 16.6 | 0.733 | 3.803 |
| | 17.4 | 0.741 | 3.823 |
| | 17.5 | 0.759 | 3.808 |
| | 17.0 | 0.704 | 3.688 |

[0157]

As seen from the results shown in Table 15, the light diffusive sheets of Comparative Examples 10 and 11 were

those that could not provide an average of slopes of the curved surface (θ_{nv}) not less than 27 degrees and not more than 70 degrees at all the measurement points.

[0158]

Then, the light diffusive sheets of Comparative Examples 10 and 11 were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light diffusive sheets of Comparative Examples 7 and 8 were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) at the center of the backlight unit (1 inch = 2.54 cm). The results are shown in Table 16.

[0159]

[Table 16]

| | | luminance (c d / m ²) | |
|----------------------------|--------------------|-----------------------------------|---------------------------|
| | | Comparative Example 10 | Comparative Example 11 |
| parallel direction | left 45 degree | 1 1 8 0 | 1 2 6 0 |
| | left 30 degree | 1 5 6 0 | 1 3 3 0 |
| | 0 degree | 1 5 6 0 | 1 2 4 0 |
| | right 30 degree | 1 5 5 0 | 1 3 3 0 |
| | right 45 degree | 1 1 8 0 | 1 2 5 0 |
| perpendicular direction | up 45 degree | 1 3 5 0 | 1 6 1 0 |
| | up 30 degree | 1 7 1 0 | 1 5 0 0 |
| | 0 degree | 1 5 6 0 | 1 2 4 0 |
| | down 30 degree | 1 7 2 0 | 1 5 2 0 |
| | down 45 degree | 1 3 6 0 | 1 6 0 0 |

[0160]

As seen from the results shown in Table 16, when the conventional light diffusive sheets were incorporated into a backlight unit, favorable front luminance could not be obtained.

[0161]

As clearly seen from the results of the aforementioned examples, the light control films of the examples exhibited superior front luminance and appropriate light diffusing property, because the rough surfaces thereof were designed so that they should satisfy the specific configuration. Further, by incorporating such light control films into a backlight unit, backlight units exhibiting high front luminance and not suffering from glare and generation of a interference pattern could be obtained.

[0162]

[Examples 17 to 20]

Four kinds of molds (23) to (26) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, an ultraviolet curing resin having a refractive index of 1.50 was poured into the molds (23) to (25), and a silicone resin having a refractive index of 1.40 was poured into the mold (26). Subsequently, the poured resins were cured, and then taken out from the molds to obtain light control films (23) to (26) having a size of 23 cm (for the direction perpendicular to the light source) x 31 cm (for the direction parallel to the light source) (light control film of Examples 17 to 20).

[0163]

Then, height data of the rough surfaces (light emergent surfaces) of the light control films (23) to (26) were measured by using a laser microscope (VK-9500, KEYENCE CORP.) with an objective lens of magnification x 50. The measurement interval in the plane was about 0.26 μm . Since one field of the objective lens of magnification x 50 is 270 μm x 202 μm , an automatic connecting function was used to obtain surface height data of a region of 1 mm x 1 mm. The measurement was performed at arbitrary 5 positions on each light control film, surface areas of the rough surfaces (A_2) were obtained by using the obtained surface height data, and the ratios ($A_r = A_2/A_1$) to the orthogonal projections of the measured rough surfaces (A_1) were calculated. Further, A_{sk} was calculated in accordance with the aforementioned formula (5) by using the same surface height data. The results obtained for the light control films (23) to (26) are shown in Table 17. Further, measurement results of hazes of the light control films

(23) to (26) measured by using a turbidimeter (NDH2000, Nippon Denshoku) according to JIS K7136:2000 are also shown in Table 17.

[0164]

[Table 17]

| | A_r | $ A_{s_k} $ | haze (%) |
|------------|----------|-------------|-------------|
| Example 17 | 2. 2 3 9 | 0. 0 9 7 | 8 2. 8 |
| | 2. 1 4 4 | 0. 1 2 4 | |
| | 2. 2 4 1 | 0. 1 0 9 | |
| | 2. 3 0 6 | 0. 0 4 9 | |
| | 2. 2 0 8 | 0. 1 1 7 | |
| Example 18 | 1. 7 8 0 | 0. 7 9 2 | 8 2. 8 |
| | 1. 8 3 4 | 0. 8 2 0 | |
| | 1. 7 0 5 | 0. 7 6 1 | |
| | 1. 7 0 8 | 0. 7 9 8 | |
| | 1. 8 0 1 | 0. 8 2 6 | |
| Example 19 | 1. 4 3 2 | 0. 2 6 0 | 8 1. 0 |
| | 1. 4 8 9 | 0. 2 5 5 | |
| | 1. 3 8 9 | 0. 2 4 8 | |
| | 1. 4 2 3 | 0. 2 6 0 | |
| | 1. 5 0 0 | 0. 2 5 4 | |
| Example 20 | 1. 8 4 3 | 0. 0 2 0 | 8 1. 7 |
| | 1. 7 7 3 | 0. 0 2 8 | |
| | 1. 8 1 6 | 0. 0 2 7 | |
| | 1. 8 9 4 | 0. 0 1 8 | |
| | 1. 8 2 3 | 0. 0 1 2 | |

[0165]

As seen from the results shown in Table 17, the surface area ratios A_r of the light control films (23) to (26) of Examples 17 to 20 were not less than 1.2 and not more than 2.5 at all the measurement points. Further, all the absolute values of A_{sk} were not more than 1.2. Moreover, all the light control films of Examples 17 to 20 had a haze of 70% or higher, and thus satisfied the optical characteristics required for obtaining favorable front luminance.

[0166]

Then, the light control films (23) to (26) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (23) to (26) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (23) to (26) are shown in Table 18 (unit is "cd/m²").

[0167]

[Table 18]

| | | luminance (cd/m ²) | | | |
|----------------------------|--------------------|--------------------------------|------------|------------|------------|
| | | Example 17 | Example 18 | Example 19 | Example 20 |
| parallel direction | left 45 degree | 1 1 1 0 | 1 1 0 0 | 1 0 7 0 | 1 1 1 0 |
| | left 30 degree | 1 7 5 0 | 1 7 9 0 | 1 8 7 0 | 1 7 6 0 |
| | 0 degree | 1 8 3 0 | 1 8 8 0 | 1 9 9 0 | 1 8 4 0 |
| | right 30 degree | 1 7 4 0 | 1 7 7 0 | 1 8 5 0 | 1 7 4 0 |
| | right 45 degree | 1 1 2 0 | 1 1 1 0 | 1 0 9 0 | 1 1 2 0 |
| perpendicular direction | up 45 degree | 1 1 3 0 | 1 0 9 0 | 1 0 0 0 | 1 1 2 0 |
| | up 30 degree | 1 8 9 0 | 1 9 2 0 | 1 9 9 0 | 1 8 9 0 |
| | 0 degree | 1 8 3 0 | 1 8 8 0 | 1 9 9 0 | 1 8 4 0 |
| | down 30 degree | 1 8 9 0 | 1 9 2 0 | 1 9 9 0 | 1 9 0 0 |
| | down 45 degree | 1 1 6 0 | 1 1 2 0 | 1 0 4 0 | 1 1 5 0 |

[0168]

It was demonstrated by the results shown in Table 18 that, for the light control films (23) to (26) of Examples 17 to 20, only by incorporating one sheet of light control film into the backlight unit, the luminance for emergent angles of 30 degrees or less could be increased, and thus strong emergent lights could be obtained for the front direction.

[0169]

[Examples 21 to 24]

Four kinds of molds (27) to (30) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, an ultraviolet curing resin having a refractive index of 1.50 was poured into the molds (27) to (29), and a silicone resin having a refractive index of 1.40 was poured into the mold (30). Subsequently, the poured resins were cured, and

then taken out from the molds to obtain light control films (27) to (30) having a size of 23 cm x 31 cm (light control films of Examples 21 to 24).

[0170]

Then, height data of the rough surfaces (light emergent surfaces) of the light control films (27) to (30) were measured in the same manner as that used in Examples 17 to 20. The measurement was performed at arbitrary 5 positions on each light control film, and surface areas of the rough surfaces (A_2) were obtained by using the obtained surface height data, and the ratios ($A_r = A_2/A_1$) to the orthogonal projections of the measured rough surfaces (A_1) were calculated. Further, A_{ku} was calculated in accordance with the aforementioned formula (6) by using the same surface height data. The results obtained for the light control films (27) to (30) are shown in Table 19 (unit of slope is "degree"). Further, by using a turbidimeter (NDH2000, Nippon Denshoku), hazes of the light control films (27) to (30) were measured according to JIS K7136:2000. The measurement results are also shown in Table 19.

[0171]

[Table 19]

| | A_r | A_{ku} | haze (%) |
|------------|----------|----------|-------------|
| Example 21 | 1. 4 5 2 | 1. 5 9 4 | 7 8. 4 |
| | 1. 4 0 3 | 1. 5 3 6 | |
| | 1. 4 4 6 | 1. 5 9 0 | |
| | 1. 5 0 0 | 1. 5 4 8 | |
| | 1. 4 0 8 | 1. 5 9 3 | |
| Example 22 | 1. 6 2 2 | 1. 9 2 5 | 8 2. 6 |
| | 1. 6 8 6 | 1. 9 4 6 | |
| | 1. 6 8 3 | 1. 8 3 7 | |
| | 1. 5 5 4 | 1. 9 6 0 | |
| | 1. 5 8 4 | 1. 8 9 0 | |
| Example 23 | 2. 2 3 9 | 1. 7 4 7 | 8 2. 0 |
| | 2. 2 2 9 | 1. 7 2 8 | |
| | 2. 1 7 9 | 1. 7 8 7 | |
| | 2. 2 1 7 | 1. 7 8 3 | |
| | 2. 2 5 7 | 1. 8 3 0 | |
| Example 24 | 1. 7 8 0 | 2. 5 9 0 | 8 2. 8 |
| | 1. 7 2 7 | 2. 5 6 2 | |
| | 1. 8 4 8 | 2. 6 3 8 | |
| | 1. 8 6 3 | 2. 5 9 2 | |
| | 1. 8 6 1 | 2. 4 8 0 | |

[0172]

As seen from the results shown in Table 19, the surface area ratios A_r of the light control films of

Examples 21 to 24 were not less than 1.2 and not more than 2.5 at all the measurement points. Further, all the values of A_{ku} were not less than 1.5 and not more than 5.0.

Moreover, all the light control films (27) to (30) of Examples 21 to 24 had a haze of 70% or higher, and thus satisfied the optical characteristics required for obtaining favorable front luminance.

[0173]

Then, the light control films (27) to (30) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (27) to (30) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (27) to (30) are shown in Table 20 (unit is "cd/m²").

[0174]

[Table 20]

| | | luminance (cd/m ²) | | | |
|-------------------------|-----------------|--------------------------------|------------|------------|------------|
| | | Example 21 | Example 22 | Example 23 | Example 24 |
| parallel direction | left 45 degree | 1 0 6 0 | 1 1 0 0 | 1 1 1 0 | 1 1 0 0 |
| | left 30 degree | 1 8 9 0 | 1 7 9 0 | 1 7 4 0 | 1 7 8 0 |
| | 0 degree | 2 0 3 0 | 1 8 8 0 | 1 8 3 0 | 1 8 6 0 |
| | right 30 degree | 1 8 7 0 | 1 7 7 0 | 1 7 3 0 | 1 7 6 0 |
| | right 45 degree | 1 0 8 0 | 1 1 1 0 | 1 1 2 0 | 1 1 1 0 |
| perpendicular direction | up 45 degree | 9 6 8 | 1 0 9 0 | 1 1 3 0 | 1 1 1 0 |
| | up 30 degree | 2 0 2 0 | 1 9 2 0 | 1 8 9 0 | 1 9 0 0 |
| | 0 degree | 2 0 3 0 | 1 8 8 0 | 1 8 3 0 | 1 8 6 0 |
| | down 30 degree | 2 0 1 0 | 1 9 0 0 | 1 8 9 0 | 1 9 1 0 |
| | down 45 degree | 1 0 0 0 | 1 1 1 0 | 1 1 6 0 | 1 1 2 0 |

[0175]

It was demonstrated by the results shown in Table 20 that, for the light control films of Examples 21 to 24, only by incorporating one sheet of light control film into the backlight unit, the luminance for emergent angles of 30 degrees or less could be increased, and thus strong emergent lights could be obtained for the front direction.

[0176]

[Comparative Examples 12 to 14]

Three kinds of molds (31) to (33) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, and an ultraviolet curing resin having a refractive index of 1.50 was poured into the molds. Subsequently, the poured resin was cured, and then taken out from the molds to obtain light control films (31) to (33) having a size of 23 cm x

31 cm (light control films of Comparative Examples 12 to 14).

[0177]

Then, height data of the rough surfaces (light emergent surfaces) of the light control films (31) to (33) were measured in the same manner as that used in Examples 17 to 20. The measurement was performed at arbitrary 5 positions on each light control film, surface areas of the rough surfaces (A_2) were obtained by using the obtained surface height data, and the ratios ($A_r = A_2/A_1$) to the orthogonal projections of the measured rough surfaces (A_1) were calculated. Further, A_{sk} was calculated in accordance with the aforementioned formula (5) by using the same surface height data. The results obtained for the light control films (31) to (33) are shown in Table 21 (unit of slope is "degree").

[0178]

[Table 21]

| | A_r | $ A_{sk} $ | haze (%) |
|---------------------------|----------|------------|-------------|
| Comparative Example 12 | 1. 4 1 3 | 2. 1 5 9 | 78. 7 |
| | 1. 3 8 6 | 2. 2 4 6 | |
| | 1. 4 3 4 | 2. 1 4 6 | |
| | 1. 4 6 2 | 2. 0 9 1 | |
| | 1. 4 4 8 | 2. 0 5 6 | |
| Comparative Example 13 | 1. 6 5 8 | 1. 4 7 9 | 81. 2 |
| | 1. 6 2 5 | 1. 5 1 8 | |
| | 1. 5 7 8 | 1. 4 9 3 | |
| | 1. 7 1 6 | 1. 4 5 6 | |
| | 1. 6 3 9 | 1. 4 4 7 | |
| Comparative Example 14 | 2. 4 0 1 | 1. 7 5 5 | 70. 4 |
| | 2. 4 6 9 | 1. 6 3 7 | |
| | 2. 2 9 4 | 1. 7 4 9 | |
| | 2. 4 9 8 | 1. 8 2 4 | |
| | 2. 3 4 2 | 1. 7 5 8 | |

[0179]

As seen from the results shown in Table 21, the surface area ratios A_r of the light control films (31) to (33) of Comparative Examples 12 to 14 were not less than 1.2 and not more than 2.5 at all the measurement points. However, all the absolute values of A_{sk} were more than 1.2.

[0180]

Then, the light control films (31) to (33) were each incorporated into a 15-inch edge light type backlight unit

(one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light control films (31) to (33) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (31) to (33) are shown in Table 22 (unit is "cd/m²").

[0181]

[Table 22]

| | | luminance (cd/m ²) | | |
|----------------------------|--------------------|--------------------------------|---------------------------|---------------------------|
| | | Comparative Example 12 | Comparative Example 13 | Comparative Example 14 |
| parallel direction | left 45 degree | 1 2 4 0 | 1 2 1 0 | 1 2 2 0 |
| | left 30 degree | 1 3 8 0 | 1 4 7 0 | 1 4 3 0 |
| | 0 degree | 1 3 2 0 | 1 4 3 0 | 1 3 8 0 |
| | right 30 degree | 1 3 8 0 | 1 4 6 0 | 1 4 2 0 |
| | right 45 degree | 1 2 3 0 | 1 2 1 0 | 1 2 1 0 |
| perpendicular direction | up 45 degree | 1 5 4 0 | 1 4 5 0 | 1 4 9 0 |
| | up 30 degree | 1 5 5 0 | 1 6 2 0 | 1 5 9 0 |
| | 0 degree | 1 3 2 0 | 1 4 3 0 | 1 3 8 0 |
| | down 30 degree | 1 5 7 0 | 1 6 3 0 | 1 6 0 0 |
| | down 45 degree | 1 5 4 0 | 1 4 5 0 | 1 4 9 0 |

[0182]

From the results shown in Table 22, it was found that when the light control films of Comparative Examples 12 to 14 were incorporated into a backlight unit, front luminance was insufficient.

[0183]

[Comparative Examples 15 to 17]

Three kinds of molds (34) to (36) on which predetermined convexo-concave profiles were formed by a laser microprocessing technique were prepared, and an ultraviolet curing resin having a refractive index of 1.50 was poured into the molds. Subsequently, the poured resin was cured, and then taken out from the molds to obtain light control films (34) to (36) having a size of 23 cm x 31 cm (light control films of Comparative Examples 15 to 17).

[0184]

Then, height data of the rough surfaces (light emergent surfaces) of the light control films (34) to (36) were measured in the same manner as that used in the examples. The measurement was performed at arbitrary 5 positions on each light control film, surface areas of the rough surfaces (A_2) were obtained by using the obtained surface height data, and the ratios ($A_r = A_2/A_1$) to the orthogonal projections of the measured rough surfaces (A_1) were calculated. Further, A_{ku} was calculated in accordance with the aforementioned formula (6) by using the same surface height data. The results obtained for the light control films (34) to (36) are shown in Table 23 (unit of slope is "degree").

[0185]

[Table 23]

| | A_r | A_{ku} | haze (%) |
|---------------------------|----------|----------|-------------|
| Comparative Example 15 | 2. 0 3 4 | 7. 2 7 0 | 7 1. 0 |
| | 2. 0 2 5 | 7. 5 7 6 | |
| | 2. 0 0 3 | 7. 2 4 9 | |
| | 2. 0 4 2 | 6. 9 3 5 | |
| | 2. 1 1 8 | 7. 4 7 5 | |
| Comparative Example 16 | 1. 5 6 5 | 1. 3 5 1 | 7 2. 8 |
| | 1. 5 1 9 | 1. 3 0 1 | |
| | 1. 5 7 1 | 1. 3 3 4 | |
| | 1. 5 9 5 | 1. 4 0 3 | |
| | 1. 6 1 2 | 1. 3 0 7 | |
| Comparative Example 17 | 1. 3 9 2 | 1. 3 1 2 | 7 2. 2 |
| | 1. 4 4 1 | 1. 3 1 0 | |
| | 1. 3 4 8 | 1. 3 1 9 | |
| | 1. 4 1 3 | 1. 3 4 9 | |
| | 1. 4 0 4 | 1. 2 5 0 | |

[0186]

As seen from the results shown in Table 23, the surface area ratios A_r of the light control films of Comparative Examples 15 to 17 were not less than 1.2 and not more than 2.5 at all the measurement points. However, all the values of A_{ku} were less than 1.5 or more than 5.0.

[0187]

Then, the light control films (34) to (36) were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and

downside), and front luminance was measured. That is, the light control films (34) to (36) were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results obtained for the light control films (34) to (36) are shown in Table 24 (unit is "cd/m²").

[0188]

[Table 24]

| | | luminance (c d / m ²) | | |
|----------------------------|--------------------|-----------------------------------|---------------------------|---------------------------|
| | | Comparative Example 15 | Comparative Example 16 | Comparative Example 17 |
| parallel direction | left 45 degree | 1 2 2 0 | 1 2 1 0 | 1 2 7 0 |
| | left 30 degree | 1 4 6 0 | 1 4 8 0 | 1 3 1 0 |
| | 0 degree | 1 4 1 0 | 1 4 4 0 | 1 2 1 0 |
| | right 30 degree | 1 4 5 0 | 1 4 7 0 | 1 3 1 0 |
| | right 45 degree | 1 2 2 0 | 1 2 1 0 | 1 2 6 0 |
| perpendicular direction | up 45 degree | 1 4 8 0 | 1 4 5 0 | 1 6 4 0 |
| | up 30 degree | 1 6 2 0 | 1 6 4 0 | 1 4 8 0 |
| | 0 degree | 1 4 1 0 | 1 4 4 0 | 1 2 1 0 |
| | down 30 degree | 1 6 3 0 | 1 6 5 0 | 1 5 1 0 |
| | down 45 degree | 1 4 7 0 | 1 4 5 0 | 1 6 3 0 |

[0189]

From the results shown in Table 24, it was found that when the light control films of Comparative Examples 15 to 17 were incorporated into a backlight unit, front luminance was insufficient.

[0190]

[Comparative Examples 18 and 19]

For commercially available light diffusive sheets (Comparative Examples 18 and 19), surface height data of rough surfaces (light emergent surfaces) were measured in the same manner as in Examples at arbitrary 5 positions on each sheet, areas of the rough surfaces (A_2) were obtained, and the ratios ($A_r = A_2/A_1$) to the orthogonal projections of the measured rough surfaces (A_1) were calculated. Further, A_{sk} and A_{ku} were calculated in accordance with the aforementioned formulas (5) and (6), respectively, by using the same surface height data. The results obtained for the light diffusive sheets of Comparative Examples 18 and 19 are shown in Table 25.

[0191]

[Table 25]

| | A_r | $ A_{sk} $ | A_{ku} |
|---------------------------|----------|------------|----------|
| Comparative Example 18 | 1. 1 5 7 | 0. 1 7 8 | 3. 4 4 1 |
| | 1. 1 0 7 | 0. 1 7 0 | 3. 5 5 9 |
| | 1. 1 6 6 | 0. 1 7 9 | 3. 5 7 8 |
| | 1. 1 1 7 | 0. 1 8 4 | 3. 5 8 4 |
| | 1. 1 5 6 | 0. 1 8 6 | 3. 3 0 9 |
| Comparative Example 19 | 1. 0 6 9 | 0. 7 2 2 | 3. 6 7 1 |
| | 1. 0 2 9 | 0. 7 0 7 | 3. 7 2 1 |
| | 1. 0 8 1 | 0. 7 4 8 | 3. 6 9 7 |
| | 1. 1 0 9 | 0. 7 1 8 | 3. 5 0 8 |
| | 1. 0 9 8 | 0. 7 2 4 | 3. 7 4 0 |

[0192]

As seen from the results shown in Table 25, the light control films of Comparative Examples 18 and 19 did not have a surface area ratio A_r not less than 1.2 and not more than 2.5 at all the measurement points.

[0193]

Then, the light diffusive sheets of Comparative Examples 18 and 19 were each incorporated into a 15-inch edge light type backlight unit (one cold-cathode tube was provided for each of upside and downside), and front luminance was measured. That is, the light diffusive sheets of Comparative Examples 18 and 19 were each disposed on a light guide plate so that the rough surface should serve as the light emergent surface, and the luminance was measured at each emergent angle for the parallel and perpendicular directions with respect to the light source (cold-cathode tubes) positioned at the center of the backlight unit (1 inch = 2.54 cm). The results are shown in Table 26.

[0194]

[Table 26]

| | | luminance (cd/m ²) | |
|----------------------------|--------------------|--------------------------------|---------------------------|
| | | Comparative Example 18 | Comparative Example 19 |
| parallel direction | left 45 degree | 1 1 8 0 | 1 2 6 0 |
| | left 30 degree | 1 5 6 0 | 1 3 3 0 |
| | 0 degree | 1 5 6 0 | 1 2 4 0 |
| | right 30 degree | 1 5 5 0 | 1 3 3 0 |
| | right 45 degree | 1 1 8 0 | 1 2 5 0 |
| perpendicular direction | up 45 degree | 1 3 5 0 | 1 6 1 0 |
| | up 30 degree | 1 7 1 0 | 1 5 0 0 |
| | 0 degree | 1 5 6 0 | 1 2 4 0 |
| | down 30 degree | 1 7 2 0 | 1 5 2 0 |
| | down 45 degree | 1 3 6 0 | 1 6 0 0 |

[0195]

As seen from the results shown in Table 26, when the conventional light diffusive sheets were incorporated into a backlight unit, favorable front luminance could not be obtained.

[0196]

Moreover, for the light control films of Examples 1 to 24, absolute values of averages (ϕ_{ave}) of angles (ϕ , -180 degrees $< \phi \leq 180$ degrees) between orthogonal projections of normals of curved surfaces of the rough surfaces projected on base planes and one side of predetermined approximately square regions were calculated. Specifically, for a square region (1 mm x 1 mm) determined at one arbitrary position on each of the light control films of Examples 1 to 24, surface profile was measured in the same

manner as that used in Examples 1 to 24, and curved surface of the rough surface was approximated on the basis of the measured height data. The angles ϕ between orthogonal projections of normals at predetermined multiple points of the curved surfaces projected on a base plane and one side of the predetermined square region were obtained, the average thereof, ϕ_{ave} , was calculated, and the absolute value thereof was obtained. As a result, the absolute value of ϕ_{ave} was 5 or less for all the light control films of Examples 1 to 24. Furthermore, also with height data obtained by rotating the square region within the film around the center of the region as a rotation axis, the absolute value of ϕ_{ave} was 5 or less irrespective of the direction of the square region.

[0197]

For the light control films of Examples 1, 9 and 17 as typical examples, change of the absolute value of ϕ_{ave} observed when the direction of the determined square was turned by 10 degrees at a time for 360 degrees is shown in the graph of Fig. 14. In Fig. 14, the vertical axis represents the absolute value of ϕ_{ave} , the horizontal axis represents the direction (degree) based on the original position of the square region, the thick line 1401 represents the result for the light control film of Example 1, thin line 1402 represents that of Example 9, and the dashed line 1403 represents that of Example 17. As seen from the results shown in the graph of Fig. 14, all the absolute values of ϕ_{ave} of the light control films of Examples 1, 9 and 17 were less than 0.5 degree even at the maximum, and the absolute value of ϕ_{ave} was not more than 5 degree.

[0198]

Since the absolute value of ϕ_{ave} was not more than 5

degree for any direction of the determined square region in the light control films of Examples 1 to 24 as described above, they did not cause glare when they were incorporated into backlight units.

[0199]

As clearly seen from the results of the aforementioned examples, the light control films of the examples were those exhibiting superior front luminance and appropriate light diffusing property, because the rough surfaces thereof were designed to satisfy the specific configuration. Moreover, by incorporating such light control films into a backlight unit, backlight units exhibiting strong front luminance and not suffering from glare and generation of an interference pattern could be provided.

[Brief Description of the Drawings]

[0200]

[Fig. 1] Sectional views showing embodiments of the light control film of present invention

[Fig. 2-1] Sectional view of a three-dimensional shape of a convex portion used in the present invention for simulating difference in emergent angle characteristics caused by the shape

[Fig. 2-2] Drawing showing an example of three-dimensional shape of a convex portion used in the present invention for simulating difference in emergent angle characteristics caused by the shape

[Fig. 3] Drawing showing results of three-dimensional simulation performed by changing shape of convex portion in an embodiment of the invention

[Fig. 4] Drawing showing results of three-dimensional simulation performed by changing shape of convex portion in an embodiment of the invention

[Fig. 5] Drawing showing results of three-dimensional simulation performed by changing shape of convex portion in an embodiment of the invention

[Fig. 6] Drawing showing results of three-dimensional simulation performed by changing shape of convex portion in an embodiment of the invention

[Fig. 7] Drawing showing results of three-dimensional simulation performed by changing shape of convex portion in an embodiment of the invention

[Fig. 8] Drawing showing results of three-dimensional simulation performed by changing shape of convex portion in an embodiment of the invention

[Fig. 9] Drawing showing results of three-dimensional simulation performed by changing shape of convex portion in an embodiment of the invention

[Fig. 10] Drawing showing results of three-dimensional simulation performed by changing shape of convex portion in an embodiment of the invention

[Fig. 11] Drawing showing an example of the rough surface of the light control film of present invention

[Fig. 12] Drawing showing an embodiment of the backlight unit of the present invention

[Fig. 13] Drawing showing an embodiment of the backlight unit of the present invention

[Fig. 14] Graph showing relations between the absolute values of ϕ_{ave} measured for the light control films of Examples 1, 9 and 17 and direction of the determined square region.

[Description of Notations]

[0201]

10 ... Light control film

11 ... Substrate

12 ... Convexo-concave layer

- 140 .. Backlight unit of edge light type
- 150 .. Backlight unit of direct type